Advanced Unmanned Search System (AUSS) Surface Navigation, Underwater Tracking, and Transponder Network Calibration

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SUMMARY

This report describes the surface navigation and underwater tracking system capabilities used in support of the Advanced Unmanned Search System (AUSS) development program. Various surface navigation and underwater tracking modes and the hardware involved are discussed. Navigation and tracking performance objectives are stated, and where available, at-sea test data results are presented to support claims. The hardware and software necessary for the deployment and calibration of a typical underwater tracking range, used for monitoring AUSS position, are discussed.

This report does not give detailed discussions of the above-mentioned topics or discuss vehicle self-navigation and tracking performed by the vehicle's Doppler sonar subsystem. It assumes the reader has previous knowledge in the methods used for surface navigation and underwater tracking of at-sea vessels and underwater vehicles. This report should leave the reader with a basic understanding of AUSS surface navigation, underwater tracking, and transponder network calibration capabilities.

Additional information is provided in the appendices. Appendix A details the main pop-up menuing system used in the Seatrac Integrated Navigation System. Appendix B consists of excerpts from transponder network calibration and navigation data files. Appendix C consists of system configuration setups for the Honeywell RS906 underwater tracking system and the Trimble 10X LORAN/GPS surface navigator. Appendix D defines acronyms and abbreviations used in the report.

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i

CONTENTS

CONTENTS (continued)

FIGURES

TABLES

INTRODUCTION

The Advanced Unmanned Search System (AUSS), under development at the Naval Command, Control and Ocean Surveillance Center, RDT&E Division (NRaD), is a free-swimming underwater vehicle that can operate in ocean depths of between 2000 and 20,000 feet. The primary missions of this vehicle are to conduct ocean-bottom search, target identification, and location marking under supervisory control from a surface support vessel. The vehicle performs the mission with the aid of sonar, electronic still camera, navigation, and propulsion subsystems. Sensor data and vehicle performance parameters are transmitted through the water column via an acoustic link communications path. Since the vehicle is free swimming (i.e., no cables exist between the surface support craft and AUSS), knowledge of the submersible's position relative to the support ship is necessary to maintain reliable communications and to ultimately mark the locations of targets that have been found during the search.

SURFACE NAVIGATION AND TRACKING

Surface navigation and tracking capabilities exist for positioning of a surface vessel in support of AUSS operations. Generally, this is done using the Navstar Global Positioning System (GPS), but Long-Range Aid to Navigation (LORAN-C) is also available during periods when GPS is unavailable or unusable. Surface navigation and tracking is also involved directly for locating the position of the AUSS submersible under certain tracking modes and geodetically marking underwater targets. For operations requiring highly accurate surface tracking (surface positioning within 3 to 6 meters), the Motorola Mini-Ranger III range-range radar tracking system is available. This system is limited to line-of-sight tracking, or approximately 40 miles from geodetically surveyed land-based transponders. Beyond the limits of Mini-Ranger III, but capable of the same positioning accuracies, differential GPS (DGPS) can be used to position a surface support ship. DGPS has been used during AUSS operations out to approximately 140 miles from a land-based DGPS reference station. Where underwater transponders have been deployed and calibrated, the system can acoustically track a surface ship within or close to the boundaries of the network. Surface navigation systems, used on AUSS, can operate as stand-alone aids to navigation or serially interfaced to an integrated navigation computer that graphically displays ship position.

GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) is a spaced-based satellite navigation system that provides positioning, velocity, and time information to a user at or near the earth's surface. The system comprises three major subsystems: the control segment, space segment, and user segment. This report deals mainly with the user segment of the GPS system. The system will eventually be available 24 hours a day, year round, for continuous two- or three-dimensional positioning. The user segment is considered a passive system, requiring only a GPS receiver and antenna to determine position from signals transmitted by space segment satellites.

The signals received by a GPS receiver provide information relating to satellite range codes and navigation data messages (ephemeris data). Ranging codes and navigation data messages are transmitted by each satellite deployed. From ranging codes, a GPS user receiver can determine transit times for radio signals between visible satellites and the user set. Transit times are converted by the GPS user receiver into ranges. Satellite position information is calculated by the user receiver using ephemeris data messages transmitted by each satellite. Using satellite position and satellite-to-user ranges, position information for the user receiver can be calculated.

The accuracy of the GPS system is maintained by the system control segment. Control segments are land-based and communicate with satellites via radio links. The control segment can also transmit system messages to satellites for distribution to users. The Standard Positioning System (SPS) mode of operation is vulnerable to actions performed on GPS by the control segment. The main objective here is to reduce system accuracy for users receiving course/acquisition (C/A) code. Advertised positioning degradation using SPS services with C/A code receivers is approximately 100 meters worldwide, 24 hours a day. If greater accuracy is required by the user station, then receivers that can use the Precise Positioning System (PPS) or differential mode GPS must be used. The AUSS GPS receiver does not have PPS capabilities, but is equipped for differential mode GPS operation.

Surface ship navigation using the SPS GPS system and the AINS software is shown in figure 1. These data were collected during a period when GPS coverage was less than 24 hours a day as shown by the absence of fixes along the left edge of the ship's track. Since November 1991, additional satellites have been placed into orbit providing nearly 24-hour, three-dimensional coverage. Figure 2 is an expanded view of the lower left-hand region of figure 1. This figure shows the jitter present in SPS GPS fixes. The ship's position using long baseline tracking is superimposed on the GPS track for comparison. A few position fixes shown in this figure show abrupt jumps of nearly 100 yards.

DIFFERENTIAL GPS

The positional error that should be expected in the standard positioning system GPS signals can be reduced by adding DGPS capabilities to a GPS receiver. The basic principles behind DGPS are fairly straightforward; however, DGPS systems are more complicated, require additional hardware, and require a geodetically surveyed reference station to obtain increased user-positioning accuracies.

The added complexity of a DGPS system lies mainly with the addition of a shore-based DGPS reference station, a data modem, and a radio transmitter. An additional receiver and modem is also necessary at the user segment to recover necessary data for adjusting satellite pseudorange values calculated by the user GPS receiver. The position information derived at the GPS reference station is compared to the known geodetic location of the receiver. The difference between the measured position and the
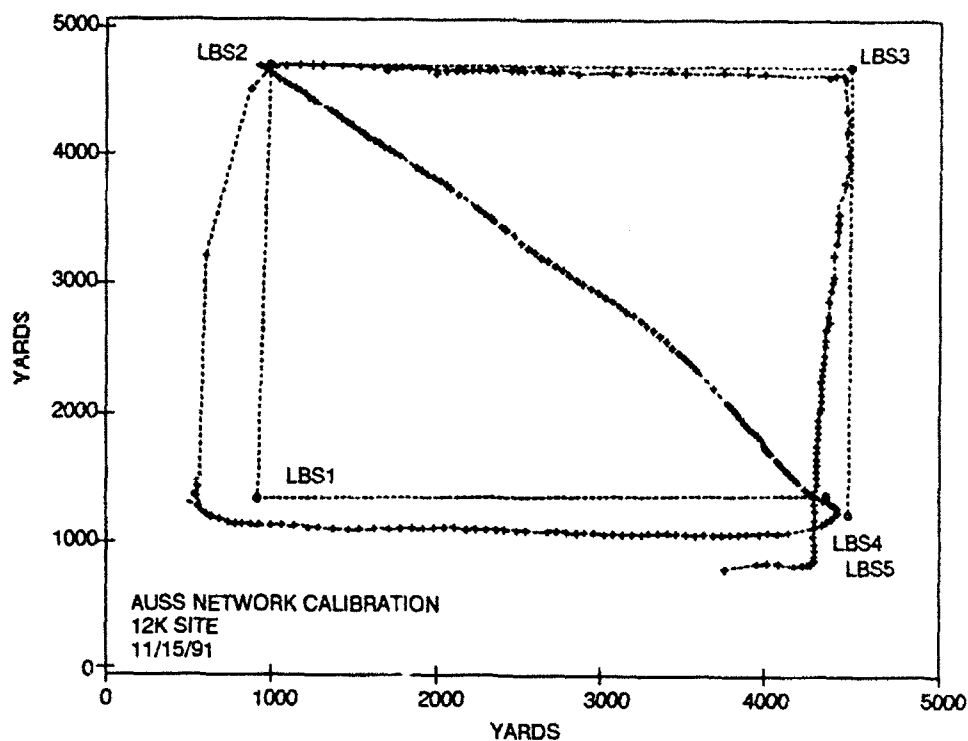
Figure 1. Surface ship's track by GPS during 12K network calibration operation.
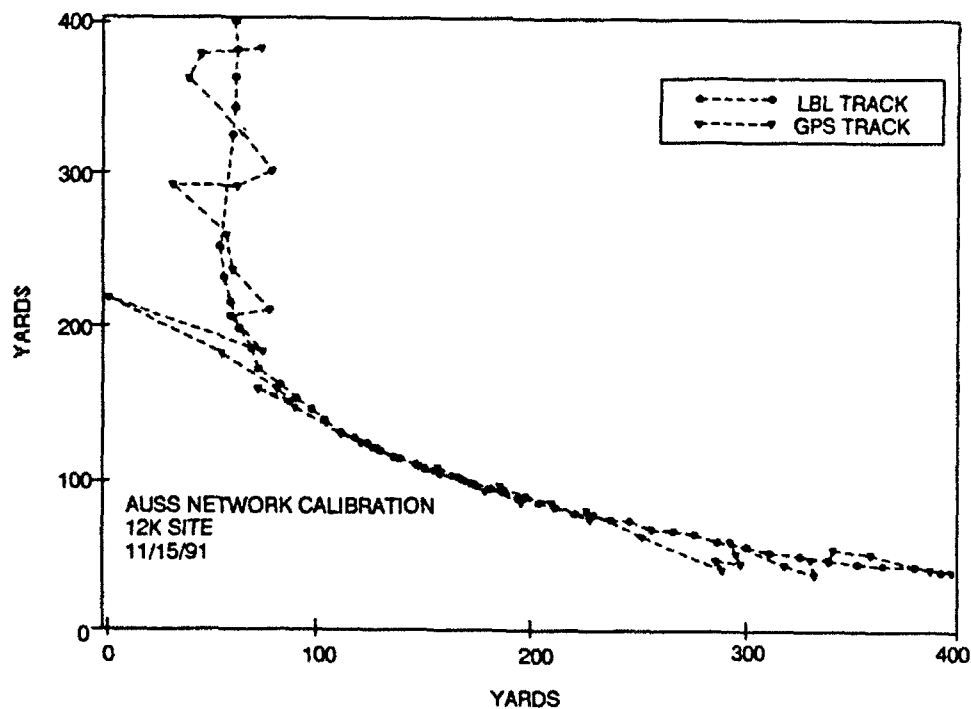
Figure 2. Recorded GPS jitter of ship's track during 12K transponder calibration operations. Long baseline ship's track superimposed for comparison.

3

known position of the reference station is used to determine corrections to the pseudo-ranges at the reference station. Pseudorange correction data for each visible satellite are then formatted by the GPS reference station in accordance with RTCM-104 standards. Formatted range corrections, in the form of serial digital data, are converted to analog signals using a modem and modulated onto an R-F carrier. The correction data are then transmitted to the remote user station. At the remote user station, additional R-F receiving equipment demodulates the pseudorange correction data. A modem converts the analog signal to a digital data stream and feeds the information to the DGPS receiver. Pseudorange corrections from the reference station are used to correct pseudoranges calculated by the user station. This process is valid only if the user station is receiving positioning information from the same satellites as the reference station.

Figure 3 shows data collected from the AUSS DGPS receiver while transiting out the San Diego harbor aboard the *Marsea* 15. The differential reference station was installed at a surveyed location at the southernmost tip of Point Loma. The figure shows that the fix-to-fix position instability is greatly reduced over what was present with SPS GPS.
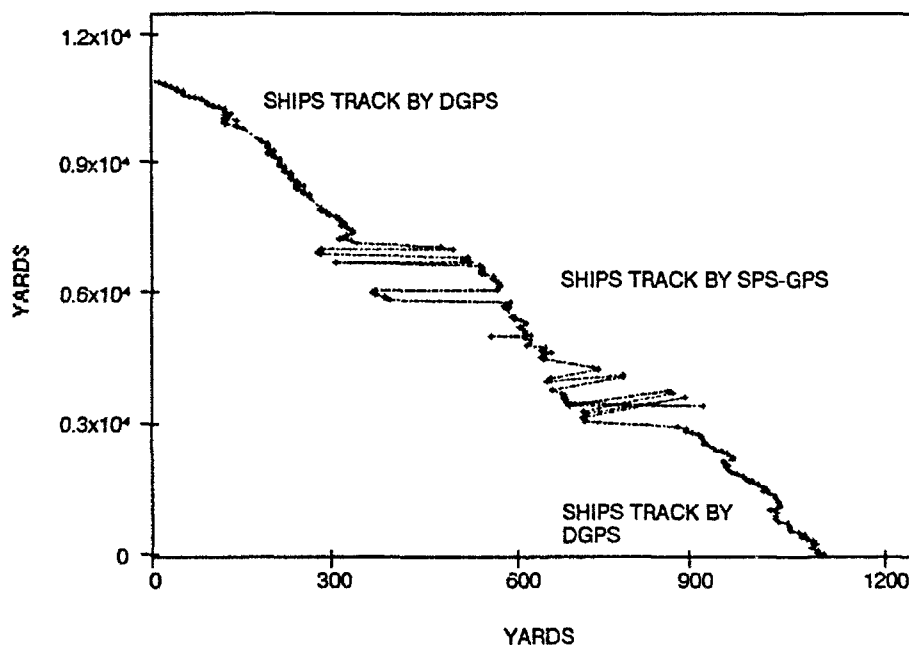
Figure 3. A comparison between differential GPS and SPS-GPS transiting out of San Diego Bay aboard the *Marsea* 15.

RANGE-RANGE RADAR SURFACE TRACKING

Radar positioning systems are used to accurately determine location of a vessel relative to R-F transponders located at fixed reference points. Fixed transponder reference points are generally surveyed in order to attain geodetic positioning. The

system operates using basic pulsed radar techniques. A radar transmitter is used to interrogate shore-based, fixed reference stations (a minimum of two shore stations are required). Upon hearing the interrogation, the reference stations transmit back to the ship's radar receiver. Transit time information for each transponder is calculated by measuring the elapsed time between the transmit pulse start time and the stop time recorded from received shore-based transponder replies. Range information is computed by dividing the round-trip transit time by two and multiplying by the speed of light.

Range information alone is not very useful for tracking purposes. Further processing of range data is performed by the Seatrac Integrated Navigation System and the AUSS Integrated Navigation System, using trilateration methods, to convert ranges to geodetic or state plane coordinates suitable for plotting. Calibrated radar ranging systems can determine ship position to within 3 to 6 meters of true position. Operating frequencies are in the C-Band of the radio spectrum, limiting the system to line-of-sight tracking only. Maximum range capabilities are approximately 40 miles from land-based transponders when used in off-shore applications.

Typical tracking plots using Mini-Ranger III are shown in figures 4 and 5. Figure 4 represents a surface ship's position recorded during a transponder network calibration operation. Figure 5 is an expanded view of a portion of figure 4 showing Mini-Ranger III jitter from position to position. Figure 6 shows the same expanded view of the ship's position using long baseline acoustic tracking. The figure shows how smooth the ship's track really is. Observed position jitter using Mini-Ranger III tracking was determined to be approximately 20 yards. Jitter is the result of signal horizontal multipath between the ship and land-based transponders. Signal multipath can be reduced by using antenna shielding techniques aboard the surface ship to eliminate reflected signals. Tracking reliability during this operation was very good. The Mini-Ranger III provided position fixes for the surface ship for better than 90 percent of the system interrogations.

LONG-RANGE AID TO NAVIGATION (LORAN-C)

LORAN-C is a low-frequency, land-based, long-range pulse continuous wave (CW) navigation system. Navigation using ground-wave radio signals is obtainable out to approximately 2500 miles from transmitting stations. Extended coverage is possible using sky waves, but performance is reduced. The operating frequency is nominally set for 100 KHz. Like GPS, LORAN-C is a passive radio navigation system. Transmitting stations throughout the world are grouped into chains (group repetition interval, or GRI) comprising a master and two or more slave stations. A receiving station receives signals from one chain of transmitters at a time to calculate position information. Signals must be received from a master station and at least two slave stations synchronized to transmit in relation to one another at predictable times. The function of the LORAN-C receiver is to determine the time differences between the arrival of the master station signal and the slave station signals. An imaginary set of hyperbolic curves is established from the time difference data. The curves are commonly referred to as
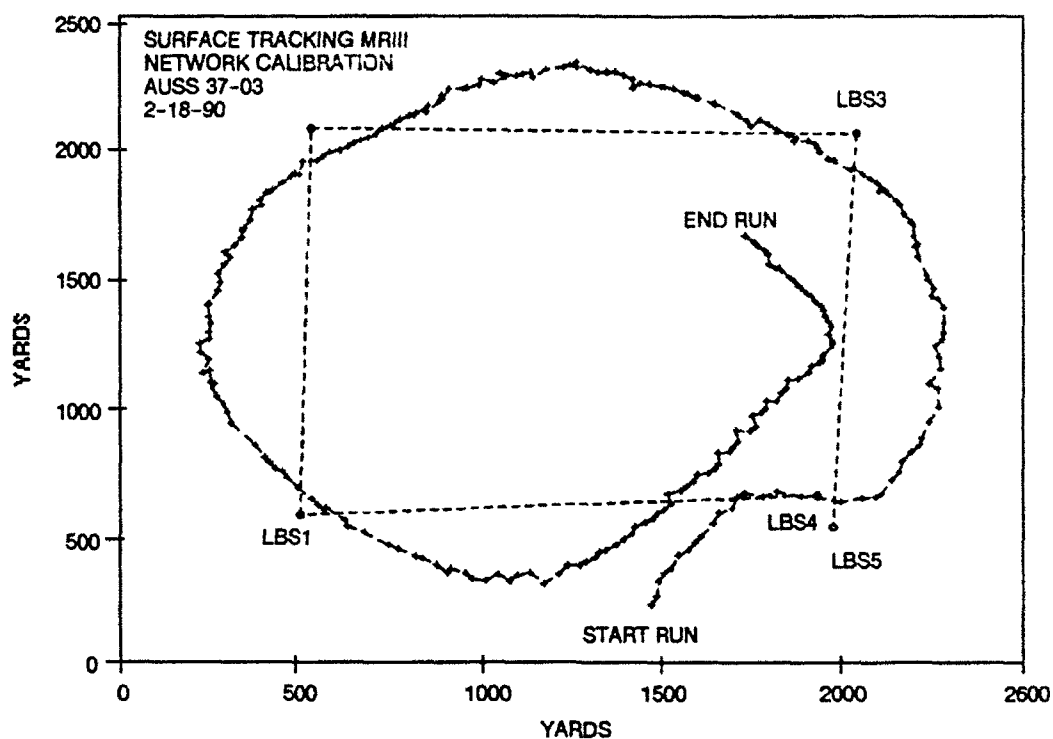
Figure 4. Typical Mini-Ranger III tracking plot of surface ship during calibration of AUSS 37-03 transponder network.
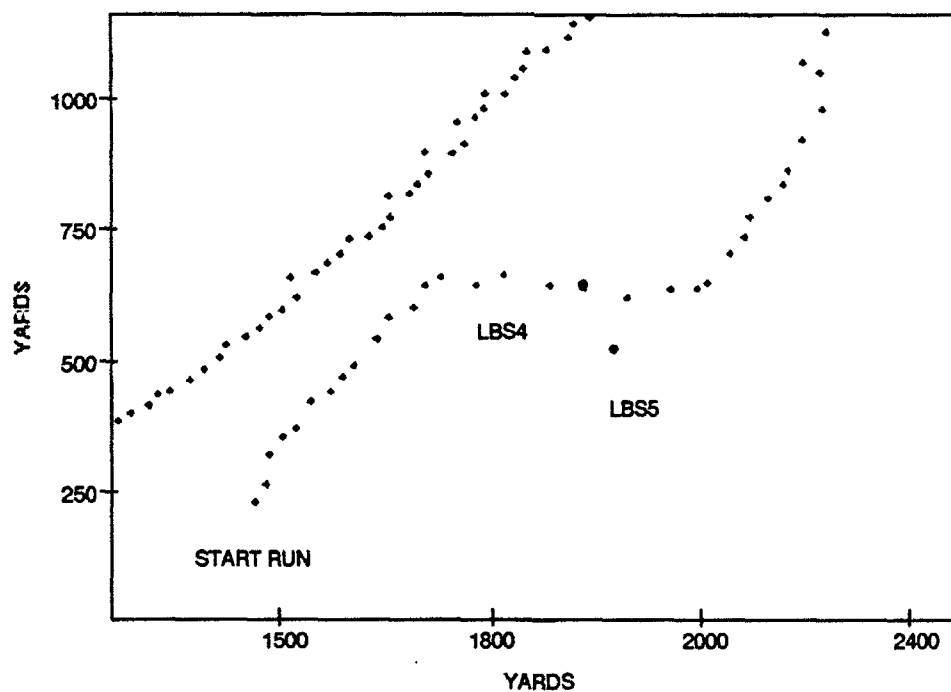
Figure 5. Expanded Mini-Ranger III tracking of surface ship showing jitter in position fixes.
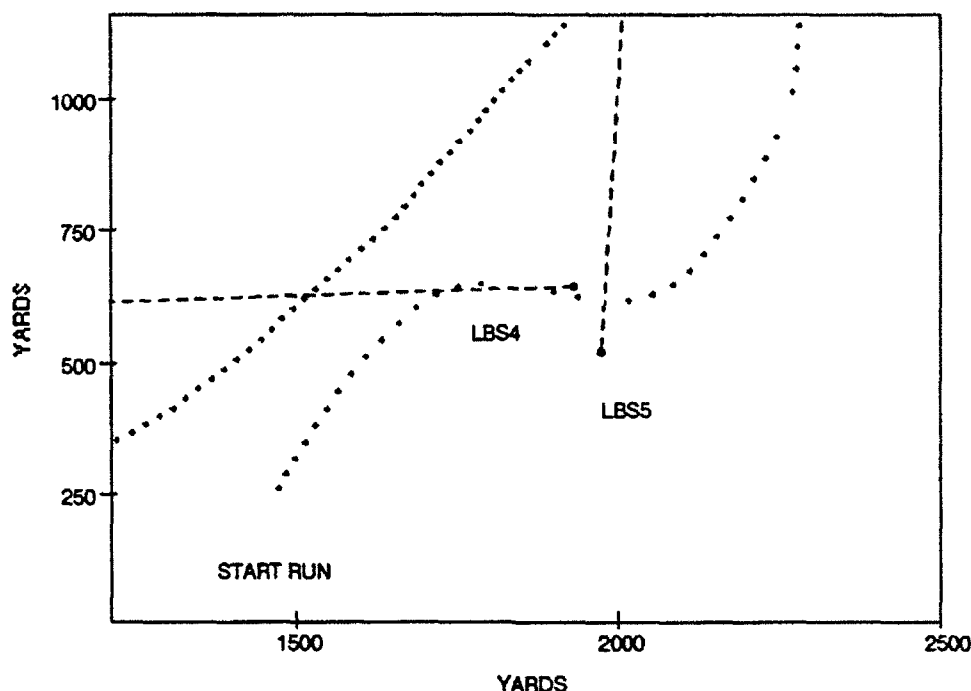
Figure 6. Expanded long baseline track of surface ship. Comparison with expanded Mini-Ranger III track shows jitter is greatly reduced.

lines of position (LOPs). The intersection of two LOPs establish a position fix of the user station. Until fairly recently, geodetic charts with LORAN-C LOPs printed on them were the only means of determining position from measured time differences of a specific GRI chain. With microprocessor-based LORAN receivers and look-up tables stored in computer memory, charts are no longer necessary for determining LORAN-C position information.

SURFACE ACOUSTIC TRACKING

Acoustic tracking of a surface ship can be conducted using short baseline (SBL) and long baseline (LBL) methods. These methods require the deployment of one or more underwater transponders to establish a reference system from which surface position is determined.

Using a single transponder system limits the surface vessel to positioning using SBL or ultrashort baseline (USBL) methods. The ship's position is tracked relative to the location of the single bottom-moored transponder. Position information is generally calculated and displayed in rectangular or polar coordinates relative to the underwater transponder. Polar coordinates are presented as horizontal range and bearing, where as rectangular coordinates are presented as X and Y offsets from the transponder reference point. For AUSS purposes, USBL surface tracking is seldom used with stationary underwater transponders; however, submersible tracking using USBL is extensive. Submersible tracking will be discussed later in this report.

7

If an underwater network of transponders has been deployed and calibrated, a surface ship can track itself relative to the network using LBL methods. Slant ranges between the surface ship and a minimum of three underwater transponders must be determined for unambiguous surface tracking. LBL tracking requires more preparation than the USBL or SBL methods, but produces very accurate position information. Typically, a surface ship can be positioned to within 1 to 2 yards of true position using LBL methods and an accurately calibrated transponder network.

Figures 7 and 8 show surface acoustic tracking using LBL methods in a calibrated transponder network. As shown in figure 7, the track is very smooth with very few position dropouts. Figure 8 is an expanded view of a portion of figure 7. Figure 8 shows very little jitter between position-to-position fixes. Figure 7 shows that tracking reliability was very good. A high percentage of the network interrogations resulted in position fixes for the surface ship. The inability to compute a surface fix is generally caused by an insufficient number of tranponder replies received from the network or a noisy ocean environment that masks reply signals. The track's smoothness indicates that signal multipath was not a problem during this operation.

SURFACE NAVIGATION AND TRACKING HARDWARE

Trimble 10X LORAN-C/GPS Receiver

The Trimble 10X LORAN-C/GPS system consists of a receiver/processor unit, a control display unit, separate antennas for receiving LORAN-C and GPS signals, and various interconnect cables tying the above units together electrically. The receiver/processor unit performs all the major functions of the 10X system. It consists of two independent receivers, one for LORAN-C and one for GPS signals, and one central processor for performing calculations and controlling keyboard and display functions. Interfacing to external computers or control systems is via three general-purpose RS422-compatible signal channels. Data output format is NMEA 0183.

The control display unit consists of a keyboard and a two-line, 16-characters-per-line, back-lit display. The unit is connected to the receiver/processor via cable. The cable length can be up to 1000 feet long, allowing for remote operation of the receiver. The control display unit is enclosed in a splash-proof housing so it can be mounted in an open environment if necessary. All data input to the 10X is through keys on the control display unit or through the RS422 serial ports. Most keys have multiple functions. Key assignment is made by the display menuing system.

The GPS and the LORAN-C antennas are both connected to the receiver/processor unit via 50-ohm coax cables. To minimize transmission loss between the antennas and the receiver/processor unit, the cable lengths should be kept as short as possible. Cable lengths of 200 feet or less are adequate for proper receiver operation. Power requirements for the 10X can be supplied by a 12- or 24-VDC source with a 30-watt rating.

Motorola Mini-Ranger III System

The Motorola Mini-Ranger III hardware consists of a range console, fixed-position reference station transponders, a mobile station receiver/transmitter assembly, and an
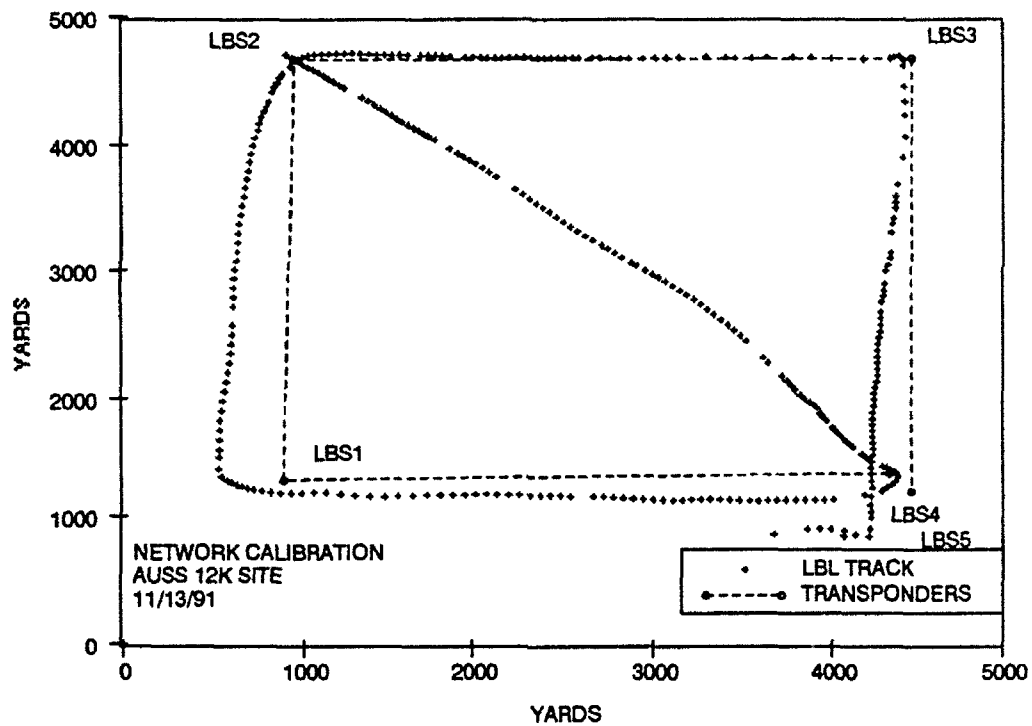
Figure 7. Surface ship's track by LBL during 12K network calibration operation.
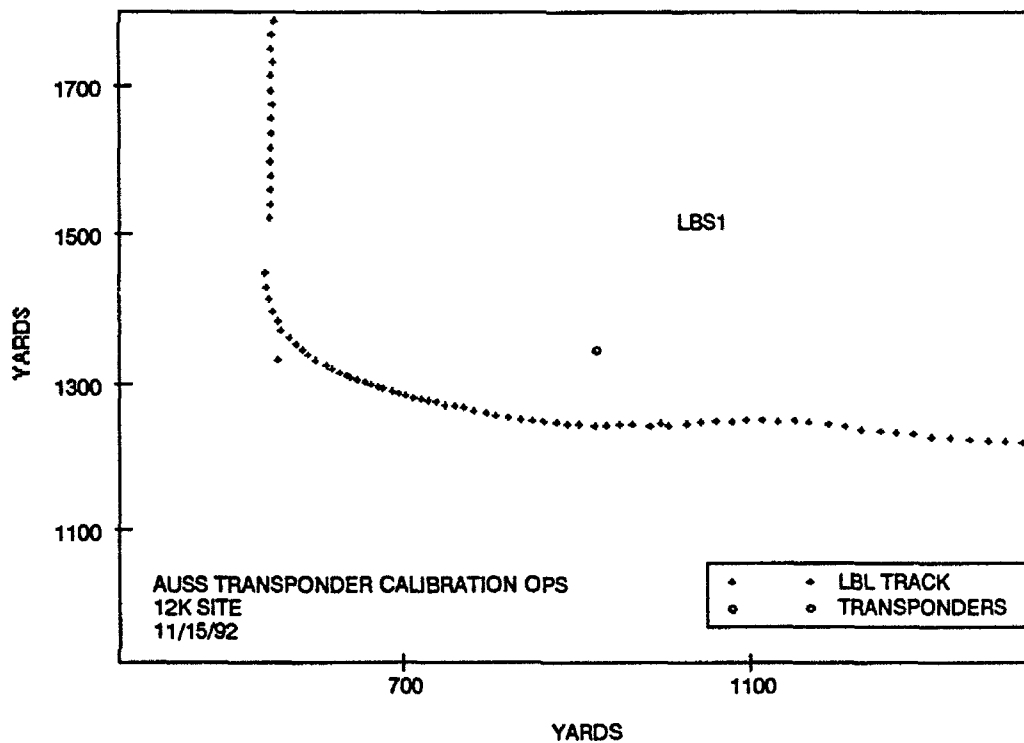
Figure 8. Expanded ship's LBL track showing fix-to-fix jitter.

9

RS232 serial interface module. The range console is the primary hardware component of this system. It controls system timing signals, generates the trigger to initiate transmit pulses, measures elapsed time between outgoing transmit pulses and returned respond pulses, displays range measurements for each system interrogation, and outputs range data to the serial RS232 serial interface module.

The mobile receiver/transmitter unit generates transmit pulses and receives pulses from the fixed-station transponders. The fixed-position reference stations receive valid interrogations from the mobile unit and transmit back a reply pulse. Transmit/receive frequency pairs are assigned to both mobile and fixed transmit/receive units. This allows for half-duplex operation for the system.

The RS232 interface module allows the Mini-Ranger III to export data to external devices, generally a computer system for further processing of the range data. The Seatrac Integrated Navigation System and the AUSS Integrated Navigation System are able to use these raw data simultaneously to convert range information into geodetic coordinates suitable for plotting.

AUSS Integrated Navigation System (AINS)

The AUSS Integrated Navigation System (AINS), in conjunction with the SonaTech NS-011 acoustic transceiver and a network of underwater transponders, can be used to track a surface vessel using LBL techniques. The acoustic transceiver, AINS, and the deployed underwater transponders form a ranging system that calculates ship's position by measuring the distances from the ship to each one of the underwater transponders. Least squared fit algorithms calculate position data. Frequencies used for acoustic tracking fall well below the radio spectrum. AUSS uses frequencies in the range of 7.0 to 17.0 kHz for all acoustic tracking. Unlike the Mini-Ranger III system, the precise location of the underwater transponders in absolute geodetic or relative coordinates is not known at the time of deployment. The network must be calibrated before accurate tracking of a surface vessel can be conducted. This process will be discussed later in the report. A well-calibrated network of underwater transponders can be used with this system to provide surface tracking accuracies on the order of 1 to 2 yards rms. Position updates depend on water depth and transponder spacing. Typically, new fixes are plotted every 10 to 20 seconds.

Honeywell RS906 Acoustic Tracking System

The Honeywell RS906 acoustic tracking system can track a surface vessel using LBL or USBL techniques. The hardware is self-contained in that it has all the components necessary to calculate and graphically display position. The transceiver consists of separate receivers for LBL and USBL operation. Four independently configurable receivers are available for LBL operation and two receivers are available for USBL operation. Individual receiver channels can be set up to receive signals ranging from 7 to 14.75 kHz in 250-Hz increments. A power amplifier that transmits acoustic pulses in the frequency range of 7 to 12 kHz is used to interrogate underwater transponders.

The system processor is used to perform position-determining calculations, keyboard and display control, system timing, frequency generation, and transponder network

calibration functions. The display console consists of a composite black-and-white monitor for displaying graphical and alphanumeric position data. Two keypads are used for system setup and data entry. Data are entered using the numeric keypad. A series of soft keys are aligned below the lower edge of the monitor. The soft keys are assigned functions as displayed on the system monitor and are used for system configuration. A typical Honeywell RS906 system configuration for LBL and USBL operations is given in appendix C.

A vertical reference unit (VRU), which consists of pitch-and-roll pendulometers, are used to remove the effects of ship motion on USBL position calculations. An external gyrocompass interface is available and used on the AUSS system to aid in USBL calculations.

For LBL operations, a single transducer is used for transmit and reception of acoustic signals. USBL operation requires an additional hyrdophone array for receiving acoustic signals. The hydrophone array must be fixed to the ship's motion for USBL operation. Fixing the transducer to the ship's motion is not a requirement for LBL operation.

The RS906 can be interfaced to external computer systems via RS232-compatible serial ports. The data port is used for interfacing the RS906 to the Seatrac Integrated Navigation System for display of LBL and USBL position information. The RS906 requires a nominal 115-Vrms, 1-KVA, 60-Hz, single-phase power source for normal operation. The system will continue to operate over a voltage range of 90 to 130 Vrms with a maximum of +/- 5 percent shift in line frequency.

SUBMERSIBLE TRACKING

Underwater submersible tracking is necessary for maintaining reliable communications between the AUSS vehicle and surface receiving equipment. Tracking also permits the system to mark the location of targets found. Tracking is done by using several traditional modes of operation, all of which involve underwater acoustics for determining submersible position. All AUSS vehicle tracking modes determine submersible position relative to locations of underwater transponders (LBL relative or absolute) or relative to the surface ship (USBL relative or absolute). The following paragraphs discuss the various modes of AUSS tracking; performance objectives and at-sea test results for each mode are addressed.

USBL TRACKING

USBL tracking of a submersible involves determining position relative to a surface ship and/or a bottom-mounted transponder. Position is displayed either in X-Y or polar coordinates with the reference zero point being the position of the surface ship, the submersible, or a bottom-mounted underwater transponder. Slant range between the surface ship and the submersible is determined by measuring the amount of time it takes an acoustic pulse to travel from the ship to the submersible and back to the ship.

11

This time is divided by two and multiplied by a selected harmonic sound speed. The result is the distance between the ship and the submersible. Submersible bearing relative to the surface ship is much more difficult to determine. The method most often used for resolving bearing is to measure signal phases from a three-element hydrophone as the acoustic wavefront impinges upon the elements. Knowing the orientation and spacing of the array, the heading of the surface ship, and the phase relationships of the signals present on each of the three hydrophones, bearing information between the ship and the submersible can be computed. The term "ultrashort baseline" is used because the element spacing in the hydrophone array is a small fraction of the wavelength of sound in water.

USBL System Description

AUSS USBL tracking is done using the Honeywell RS906 system. This system has all the hardware necessary to transmit, receive, process, and display information fixing the location of a submersible relative to a surface craft or other bottom-moored transponders. The RS906 can be interfaced to an external computer system via RS232-compatible serial ports. This interface is used to display USBL tracking data on the Seatrac Integrated Navigation System computer. This feature is discussed in more detail later in the report.

The AUSS vehicle is equipped with two onboard transponders that can be used in conjunction with USBL tracking. The STINGER transponder and its transducer is an integral subsystem of the vehicle electronics and mechanical structure. The STINGER is interrogated at a frequency of 9 kHz and responds with a 10-msec pulse of 7 kHz. The transponder turnaround time is 10 msec. This transponder is powered by the internal vehicle power system. The second transponder installed on the vehicle is a SonaTech NT029. The transponder is located in the free-flooding section of the AUSS vehicle's aft tail cone. The transponder is housed in its own pressure housing and is self-contained (i.e., powered off its own battery). This transponder will continue to operate if all vehicle power systems shut down due to failure. The unit is interrogated at 9 kHz and responds with a 10-msec pulse at 13.5 kHz. Transponder turnaround time is 3 msec.

USBL System Capabilities and Performance Objectives

The Honeywell RS906 can track the AUSS vehicle to the AUSS design depth of 20,000 feet. The tracking system should be capable of determining position out to the maximum horizontal standoff distance between the surface ship and AUSS. For the AUSS vehicle operating at 20,000 feet, the tracking system should be capable of tracking out to a 20,000-foot horizontal distance.

Under normal vehicle operating conditions, the STINGER transponder is active for as long as the vehicle and its internal battery are healthy. Normal vehicle operating time while conducting search at 4 to 5 knots is approximately 10 hours with a fully charged silver-zinc battery. The STINGER transponder should not be counted on for tracking after the energy of the internal battery is depleted or AUSS is shut down due

12

to system malfunction. If the STINGER transponder is unavailable, USBL tracking can be conducted using the external NT029 transponder. The NT029 has its own internal battery source that is not dependent upon the vehicle. The NT029 battery operating life is 120 days using an alkaline power pack. The maximum number of transpond cycles is 80,000.

USBL Tracking Performance Test Results

USBL tracking accuracy is generally stated as a percentage of range between the surface ship and the underwater device being tracked. More specifically, published claims by manufacturers of USBL tracking hardware state that system accuracy is approximately 1 percent of range. Figure 9 shows USBL tracking expectations for the AUSS vehicle operating in a hovering mode. Tracking data were collected while the AUSS submersible was operating in approximately 4000 feet of water. In the hover mode, AUSS is subject to movement about a point within a circle of radius of 10 feet. Relative tracking was conducted using the Honeywell RS906 tracking system operating in the transpond mode. Raw tracking data from the RS906 were used by the Seatrac INS to calculate and record position information. The data were then normalized using the mean position value as the zero point. All position fixes recorded were within a 50-yard radius of this mean value, or approximately 3.75 percent of range.

The transformation of relative USBL position fixes of the AUSS vehicle to geodetic coordinates is conducted by the Seatrac Integrated Navigation System. The transformation will inject additional errors into the position fix due to errors in the surface fix. Depending upon the the method of surface tracking, this error could range from a few yards (using Mini-Ranger III or DGPS) to several hundred yards (LORAN-C).

LBL FISH-CYCLE TRACKING

LBL fish-cycle tracking is a technique for determining the position of an underwater vehicle, equipped with a fish-cycle transponder, within the boundaries of an underwater transponder network. A fish-cycle transponder is similar to a network transponder except that it is interrogated at a frequency different from the network and responds at a frequency that is the same as the network interrogation frequency. Tracking is relative to deployed transponders moored to the ocean floor. Position information is calculated and displayed using a rectangular coordinate system, usually referenced to one of the underwater network transponders. Before tracking can be conducted, the network transponders must be calibrated to determine their positions relative to one another. If geodetic tracking is required, the network calibration must undergo further processes to assign each transponder specific geodetic points.

The fish-cycle method requires two interrogation cycles from the surface ship to determine the location of the submersible. The first cycle determines ship position by measuring round-trip transit time of an acoutic pulse and calculating slant ranges between each bottom-mounted transponder and the surface ship. The second cycle determines submersible position by measuring two different time periods. The first

13
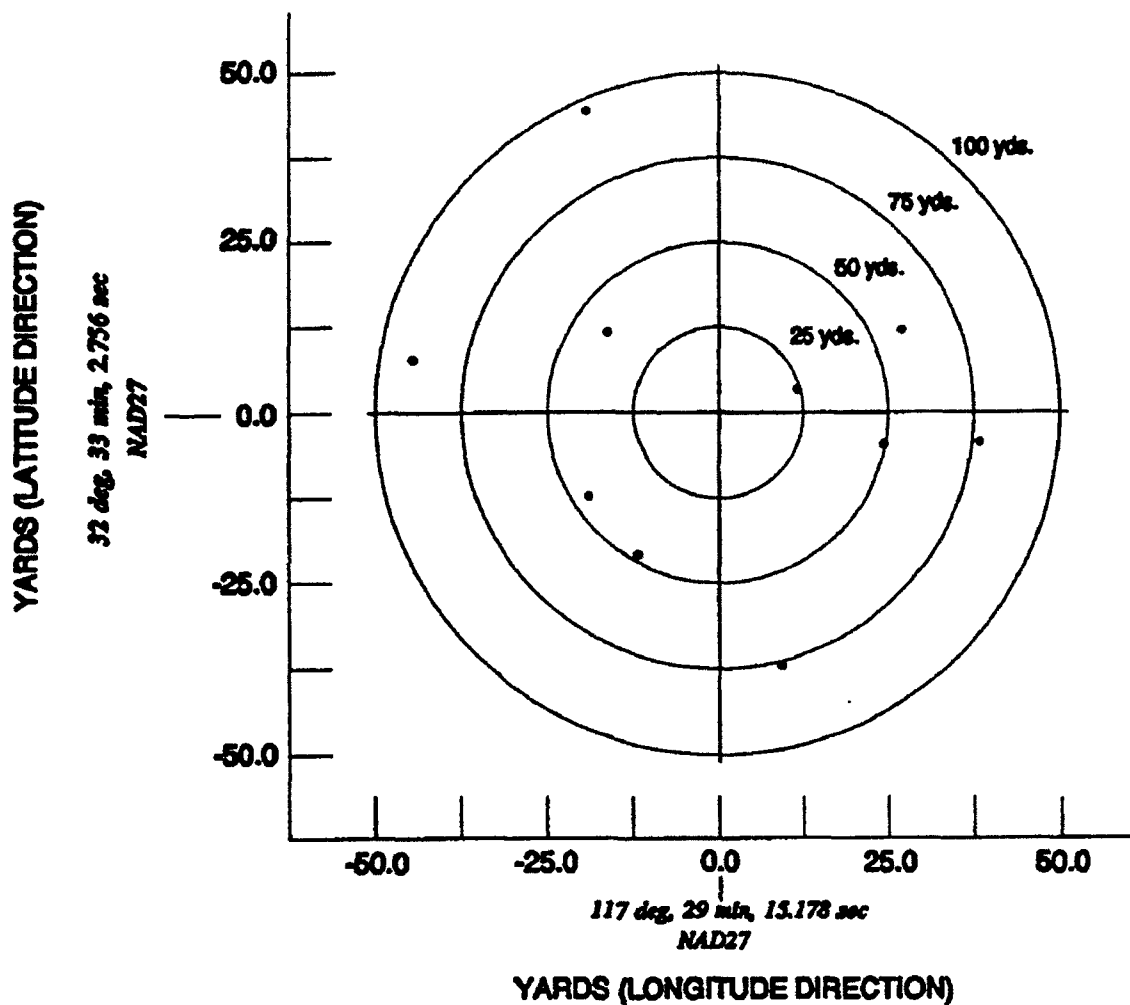
Figure 9. USBL fixes of AUSS vehicle in hover mode over target (pleasure craft found during AUSS dive 41).

period measures the round-trip time for an acoustic pulse between the ship and the submersible. The second period measures the round-trip times for an acoustic pulse traveling from the ship to the submersible, to each network transponder, and back to the ship. Submersible-to-transponder slant ranges are calculated by subtracting ship-to-submersible slant range plus ship-to-transponder slant range from the round-trip range of a pulse for each transponder. Vehicle depth can also be determined using LBL fish-cycle techniques.

LBL Fish-Cycle System Capabilities and Performance Objectives

LBL tracking is performed by using either the Honeywell RS906 or AINS. Both systems will track a surface ship or a ship and the AUSS vehicle within the confines of an underwater transponder network. The RS906 is strictly a relative tracking system. There are no provisions tying the calibrated LBL network to absolute geodetic

14

coordinates except through the Seatrac Integrated Navigation System. Therefore, all positioning is done relative to a selected reference point. The reference point selected is usually one of the underwater transponders. In contrast to the RS906, AINS can track in either relative or absolute geodetic coordinates. Geodetic tracking is possible because the X-Y coordinates of the transponders can be assigned geodetic positions in the form of Lambert state plane coordinates. Additional processing is available to convert Lambert coordinates to geodetic latitude and longitude if and when necessary.

LBL fish-cycle tracking, in conjunction with a well-calibrated underwater transponder network, can be expected to position a surface ship and submersible within 1 to 2 yards of true position within the network. This accuracy is highly dependent upon the known locations of the transponders, and to a lesser degree the value used for the speed of sound in water.

Acoustic tracking reliability is dependent upon communications between the surface ship, transponders, and the submersible. Ranges from a minimum of three transponders for each cycle of a fish-cycle fix are necessary for three-dimensional positioning of a submersible. Computed ranges must represent direct paths between all systems involved. Receiving returns from less than three transponders or ranges based upon indirect acoustic paths produce no position information of erratic jumps from the true surface or submersible path (commonly called "position flyers").

AUSS incorporates several design features that enhance tracking performance. Features include baffling of surface and vehicle transducers to eliminate unwanted bottom or surface bounce signals. An omnidirectional vehicle projector is used to assure that all transponders can hear network interrogations during the fish cycle. Lock-out times are designed into the vehicle transponder to prevent unwanted network interrogations by the vehicle. Surface acoustic receiver run-out times are established to narrow listening periods for network transponder replies. Transponder reply frequencies are spaced at 500 Hz to prevent unwanted surface receiver cross-talk.

LBL Fish-Cycle Performance Test Results

Figures 10 and 11 illustrate LBL tracking capabilities observed during AUSS dives in 11,500 and 2500 feet of water, respectively. Figure 10 represents LBL fish-cycle data taken while the AUSS vehicle was attached to a line moored to the ocean bottom. The data were taken using the NS-011 acoustic transceiver and AINS. Vehicle depth was approximately 11,350 feet, at an altitude of 150 feet. Vehicle thrusters were all inactive while attached to the mooring line, so vehicle movement was minimal. All position fixes recorded in figure 10 are clustered within a 6-yard radius of the mean value. Furthermore, the majority of the fixes are within a 2- to 3-yard radius of the mean value. These results are consistent with the network calibration rms errors.

Figure 11 shows dynamic vehicle and surface ship tracking using LBL fish-cycle methods. The data were collected using the NS-011 acoustic transceiver and AINS. The tracks recorded for the surface ship and AUSS show reliable position fixing with very few flyers and dropouts. Tracking jitter for each track is consistent with LBL ship fixes determined during the transponder network calibration, typically 2 to 3 yards.

15

Figure 10. LBL fish-cycle fixes of AUSS vehicle attached to line moored to the seafloor. Vehicle depth: 11,350 feet. Vehicle altitude: 150 feet.

Figure 11 also shows the depth calculation and CRT plotting capabilities of AINS. During the course of the vehicle's track, figure 11 indicates that AUSS depth was continuously changing.

LBL RELAY MODE TRACKING

LBL relay mode tracking is similar to fish-cycle mode tracking. The major difference is that nonacoustic means are used to determine surface ship position (i.e., GPS, LORAN-C, Mini-Ranger III, DGPS) within the network. Since transponder depths and locations are known geodetically, slant ranges between the surface ship and each network transponder can be calculated rather than measured by the NS-011. Submersible position is determined by periodic surface ship acoustic interrogations of the vehicle, which in turn interrogates the LBL network. The round-trip acoustic travel times

16
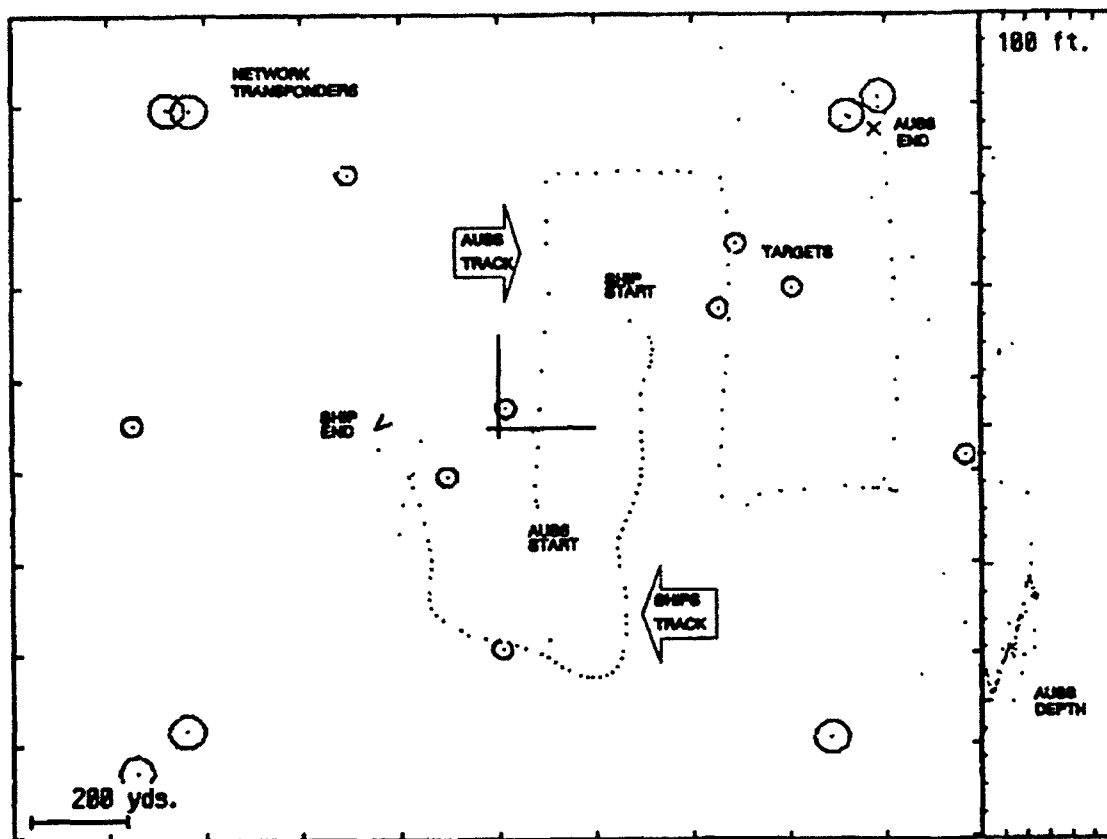
Figure 11. LBL surface and submersible tracking during AUSS side-look sonar run using AINS software.

between the surface ship, the submersible, and each network transponder are then used to determine the vehicle's position using the fish-cycle mode algorithms.

Relay Mode Tracking System Capabilities and Performance Objectives

Relay mode tracking using this technique can only be conducted in a calibrated underwater transponder network. Furthermore, the transponder locations must be pinpointed in absolute geodetic coordinates (i.e., Lambert state plane coordinate system).

A few characteristics of relay mode tracking are worth noting. An underwater network of transponders calibrated in relative terms cannot be used for relay tracking. The geodetic surface ship positions would be meaningless for computing slant ranges between relative transponder positions and geodetic ship positions. The number of surface ship ping cycles required for computing submersible position is reduced from two (fish-cycle mode) to one in the relay mode. Relay mode tracking accuracy is influenced by two independent factors. The first factor involves the accuracy of the known geodetic positions of the network transponders, and the second factor involves the accuracy of the ship's position fix within the network. Surface fixes can vary from a few yards using Mini-Ranger III or DGPS to hundreds of yards using LORAN-C. C/A code

17

GPS will typically determine submersible position to within 100 yards using relay mode tracking.

Relay Mode Tracking Perfomance Test Results

LBL relay mode tracking of the AUSS vehicle is shown in figure 12. The data plotted in figure 12 represent position fixes while AUSS was attached to a line moored to the ocean bottom. The vehicle depth and altitude was 11,350 and 150 feet, respectively. Vehicle thrusters were not operating, so the only forces acting on AUSS that could influence position were ocean currents. The GPS was used for surface navigation during data collection. The figure shows that the majority of the submersible fixes are clustered within a 12-yard radius of the mean fix value (the graph 0,0 point). GPS was well-behaved during this period as evidenced by the tight clustering of the vehicle fixes. The cluster pattern is primarily dependent upon surface ship fixes and, to a lesser degree, on the computed slant ranges determined during the acoustic cycle.
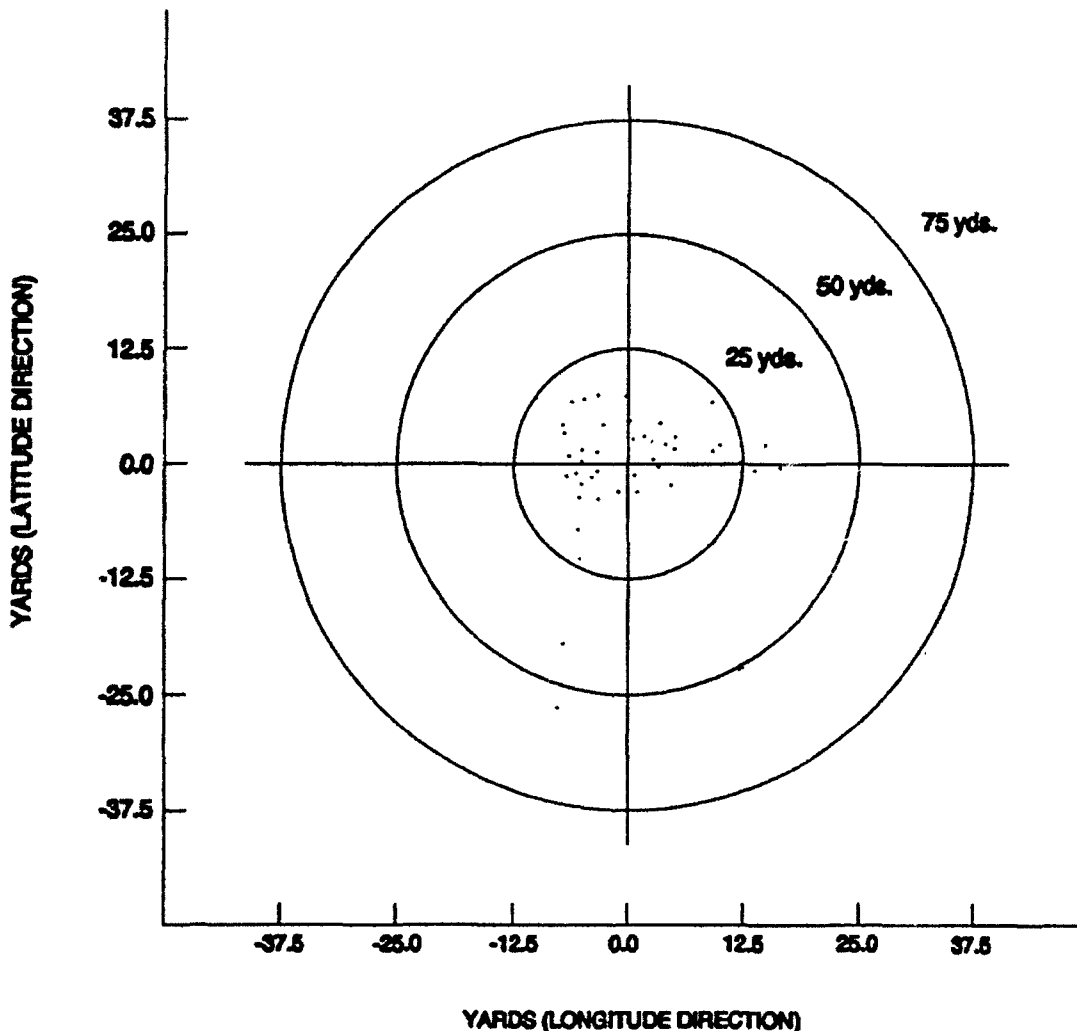
Figure 12. Relay mode tracking of AUSS vehicle attached to a line moored to the seafloor. Vehicle depth: 11,350 feet. Vehicle altitude: 150 feet.

18

PASSIVE MODE TRACKING

Passive tracking is a nontraditional method of submersible tracking within a network of calibrated underwater transponders. Most of the proven methods require surface ship acoustic interrogations of the underwater transponder network. A submersible vehicle tracking mode has been developed that requires no surface ship acoustic interrogations to determine AUSS vehicle position. The passive tracking method uses principles adopted from surface ship positioning by LORAN-C radio navigation. Since radio transmissions are useless for underwater communications, acoustic transmissions are used for passive tracking.

Vehicle tracking using passive methods requires inputs from surface and subsurface tracking devices. Just as with relay tracking, passive tracking requires a transponder network calibrated in absolute geodetic coordinates. The surface ships's position is determined using GPS, DGPS, LORAN-C, or Mini-Ranger III receivers. The vehicle's position is determined using time differences measured by the acoustic transceiver (SonaTech NS-011) and AINS in response to AUSS vehicle interrogations.

As mentioned earlier, the surface ship listens for AUSS vehicle interrogations and network transponder replies during passive mode tracking. Detecting the vehicle interrogation, the surface acoustic transceiver enables its channel receivers and starts a system timer. The system timer is used to measure elapsed times between the reception of the network interrogation and the individual transponder replies. The recorded times for each tracking cycle represent time differences between each network transponder reply and the detected vehicle interrogation. Time differences from the NS-011 are converted by AINS software into range differences for each transponder. Measured range differences are compared to calculated range differences determined by computer using iterative selection of geodetic vehicle positions within the transponder network. The iterative selection of vehicle positions is conducted until the residual error between the measured range differences and calculated range differences is minimized. The calculated X, Y, Z vehicle coordinates are plotted on the graphics monitor and the tracking cycle is then restarted. The iterative search process for determining vehicle position takes only a few seconds to compute.

During the course of an AUSS search mission, sensor and telemetry data are constantly being transmitted acoustically by the vehicle to the surface ship through the water column (no electrical cables). The vehicle, from time to time, stops transmitting uplink data and listens for downlink commands from the surface ship. The tracking cycle begins at the vehicle with a network interrogation. Interrogation times are determined by commands sent to the AUSS vehicle by the systems operator. The command sets up minimum time periods between interrogations and two time windows identified as the pre-ping and post-ping time intervals. The vehicle ping is issued during quiet periods that meet minimum time period requirements. Within a valid ping window, the pre-ping parameter will determine the exact time the vehicle ping is issued. Following the interrogation ping, a post-ping time period is allowed to elapse before sensor and telemetry data are again transmitted. Pre-ping and post-ping time periods enhance passive tracking capabilities by allowing sufficient quiet times for all tracking hardware to

hear vehicle interrogations and transponder replies. Without pre-ping and post-ping time periods, the possibility exists that vehicle interrogations will be masked by vehicle acoustic link transmissions, rendering passive tracking unusable. Interrogations must be heard by a minimum of three network transponders and the surface acoustic transceiver during each cycle for position fixes to be calculated.

Passive Tracking System Capabilities and Performance Objectives

When LBL vehicle tracking methods are used to determine the AUSS vehicle position, passive tracking enhances vehicle search rate by reducing the time necessary to determine the submersible fix. The system also becomes more automated because little or no intervention is necessary by navigation operators. Once the system is set up, an interrogation ping from the vehicle and transponder replies are all that are necessary to calculate and display vehicle position and depth information. As with relay mode tracking, passive mode tracking can determine vehicle position to an accuracy no better than the position fix of the surface ship. Therefore, surface navigation systems such as Mini-Ranger III and DGPS will produce a more accurate submersible fix than will C/A code GPS and LORAN-C receivers.

Passive Tracking Performance Test Results

Passive tracking of the AUSS vehicle has been conducted at deployed depths of 2400 and 11,500 feet with good results. Figure 13 is a plot of passive tracking data of the AUSS vehicle while attached to a tether moored to the ocean bottom. GPS C/A code data were used for surface navigation. The plot in figure 13 shows that individual fixes are clustered within a circle 100 yards in diameter. The fix-to-fix jitter is due to the position fixes of the surface ship using GPS and limited movement of the vehicle due to bottom currents. Jitter could be reduced using DGPS or Mini-Ranger III surface navigation hardware. Figure 13 shows a worst-case scenario for open-ocean operation using GPS signals. Figure 14 shows dynamic tracking of the AUSS vehicle deployed at an ocean depth of 2400 feet. Vehicle speed during tracking was approximately 4 knots. The surface ship, using GPS, was moving at a speed over ground of between 2 and 3 knots.

SUBMERSIBLE TRACKING HARDWARE REQUIREMENTS

Tracking AUSS to its design depth of 20,000 feet requires hardware (i.e., acoustic transceivers, transducers, and deep-ocean transponders (DOTs)) that can generate sufficient signal source levels, detect weak acoustic wave fronts, and withstand extreme hydrostatic pressures. Receiving amplifiers must have low internal noise floors, high gain, and low power consumption. Low power consumption is critical for battery-operated DOTs deployed for extended periods of time. Hardware enclosures must be of corrosion-resistant material and capable of withstanding pressures to 10,000 psi. Table 1 summarizes typical AUSS hardware tracking specifications.

Table 1. Acoustic transceiver characteristics (typical).

Source Level	>190 dB re 1 µPa @ 1 m	Acoustic
Transmit Interrogation Frequency	7.0 to 17.0 kHz	100-Hz Steps, Programmable
Interrogation Pulse Width	5.0 ms to 1.0 sec	Programmable
Repetition Rate	1.0 to 60 sec	Programmable
Receiver Sensitivity	<+75 dB re 1 µPa	Acoustic
Receiver Frequency Range	7.0 to 17.0 kHz	250-Hz Steps, Programmable
USBL Receiver Channels	4 Minimum	Honeywell RS906
LBL Receiver Channels	16 Minimum	SonaTech NS-011
Command Code Transmissions (Formats)	Code Modulated Carrier; Single Or Dual Signal	SonaTech NT020 & NT029 Benthos XT6000/TR6000

INTEGRATED NAVIGATION AND TRACKING SYSTEMS

SEATRAC INTEGRATED NAVIGATION SYSTEM

The heart of surface navigation and underwater tracking is the Integrated Navigation System (INS) computer running the Seatrac software. The computer uses an IBM industrial 7552 housing and 80386 CPU and 80387 coprocessor. The INS reads data serially from attached sensors and displays surface ship and underwater submersible position and related data on text and graphics CRT screens.

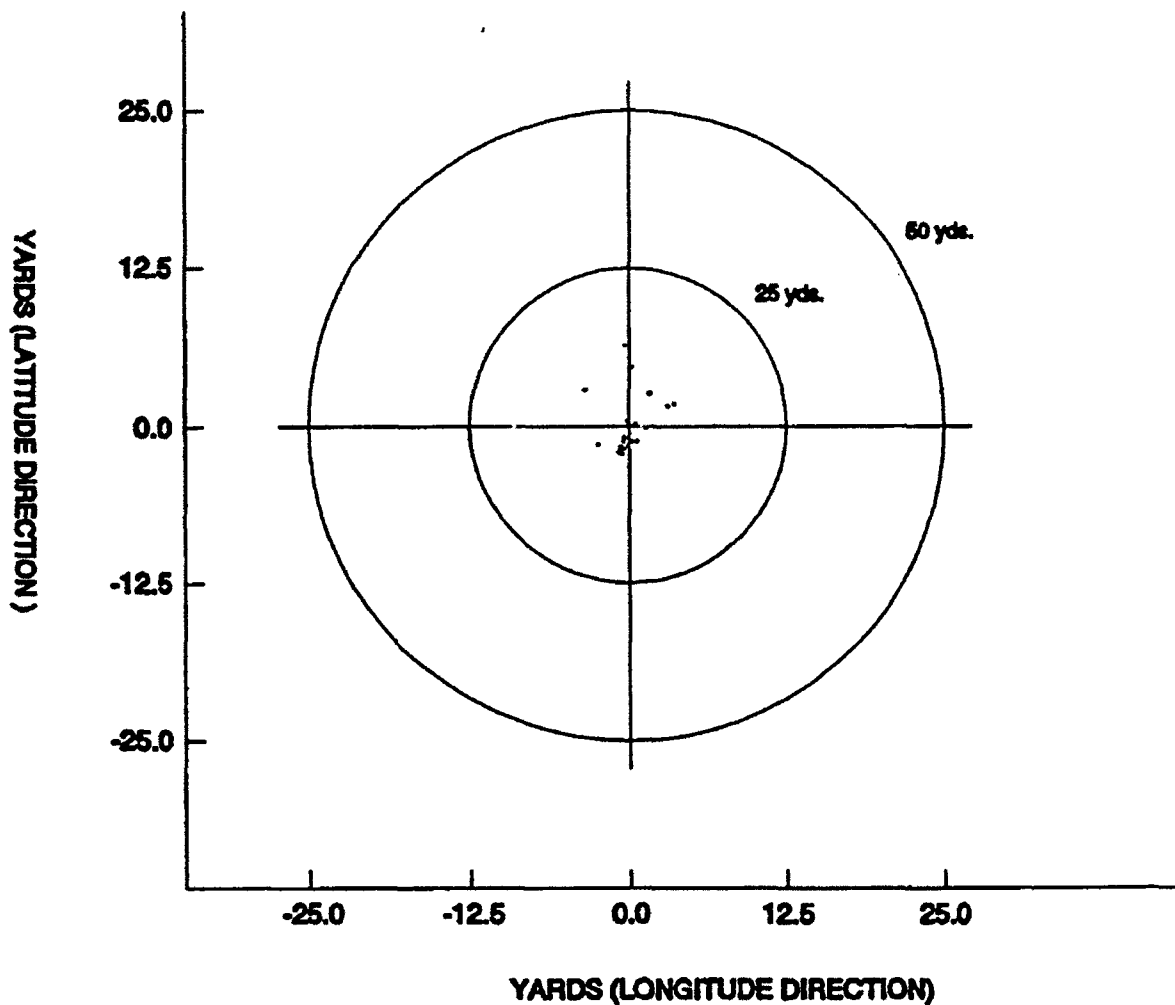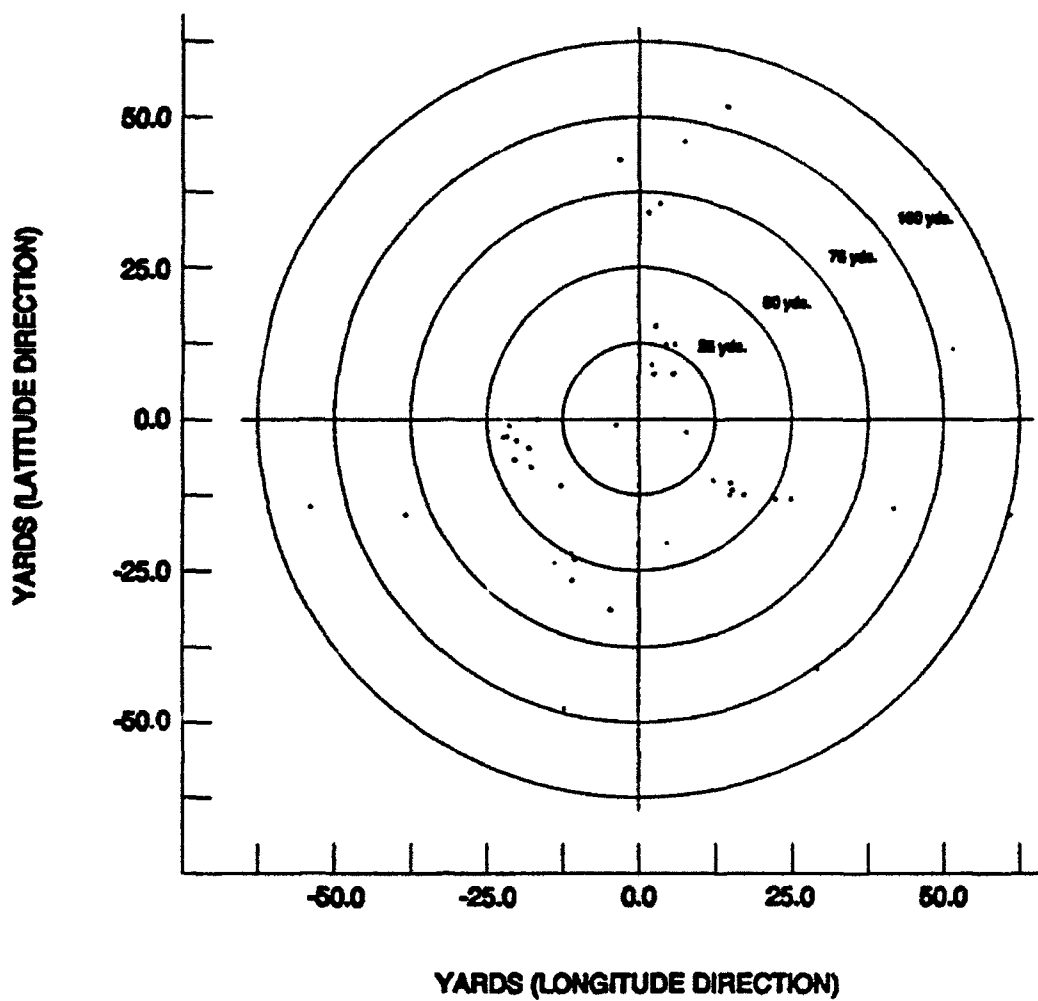Figure 13. Passive mode tracking fixes of AUSS vehicle attached to a line moored to the seafloor. Vehicle depth: 11,350 feet. Vehicle altitude: 150 feet.

22
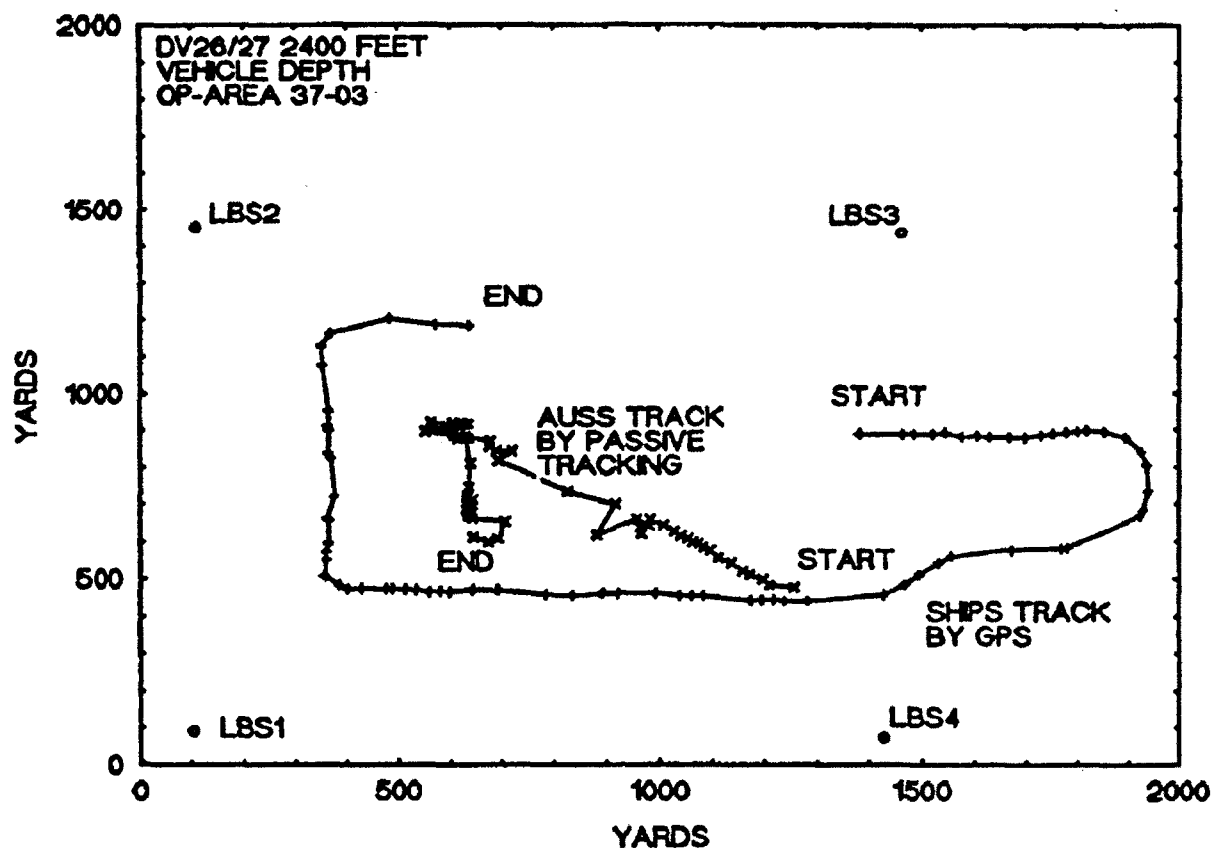
Figure 14. Dynamic tracking of the AUSS vehicle at an ocean depth of 2400 feet.

A primary component of this surface navigation and tracking system is the Seatrac software package developed by Seaquest Associates of Mystic, CT. The software has been tailored for specific use of surface and underwater tracking sensors. Navigation information, from up to three surface navigation or underwater tracking sensors, can be processed on a priority basis to plot ship and submersible position.

Data in geodetic format are converted by the Seatrac software for plotting in an X-Y Cartesian coordinate system. Projection systems supported include Lambert conical, universal transverse Mercator, and a user grid defined by an oblique transverse Mercator projection. The software loads and runs on any 80386-based personal computer with math coprocessor. Hardware-specific serial input/output and video graphic adapters must be installed for the program to execute properly. Hardware-specific components are specified in figure 15. Ship and submersible position fixes are plotted on a high-resolution graphics color monitor and, if required, an X-Y pen plotter for hard-copy reference. The software supports a nongraphic color text monitor for display of system configuration, mission profiles, and navigation-related data such as ship's position, course over ground (COG), speed over ground (SOG), heading, vectoring, and time-to-go (TTG) calculations. Hard-copy alphanumeric information is printed to a dot

23

matrix printer via the computer LPT1 printer port. The system supports a gyrocompass through a direct parallel interface or through the RS906 LBL/USBL tracking sensor. Figure 16 is a block diagram of the present AUSS hardware configuration running the Seatrac software.

IBM 7552 INDUSTRIAL ENCLOSURE

DIGI COM 8i I/O	ARTIST II GRAPHICS ADPTR	NETWORK INTERFACE CARD	80386 CPU	VGA CARD	FLOPPY/HD CONTROLLER	PARALLEL INTERFACE CARD	SPARE SLOT	FLOPPY/HARD DISK DRIVES

Figure 15. Seatrac INS computer card slot assignment.

Seatrac Software Description

The Seatrac INS software is commercially developed, maintained, and documented. The software comprises two basic modules, one for configuring the navigation software, and the navigation software. The configuration software should be run before attempting to operate the navigation software. These two software modules will be discussed separately in the following paragraphs.

The Seatrac configuration utility is used to establish a basic system configuration for the integrated navigation program. The software uses a series of pop-up menus that allows the user to select hardware options and enter necessary data required to execute the INS program. The opening menu is shown in figure 17.

The devices selection configures the program for the external sensors attached to the INS computer. The options available for the AUSS system include the Honeywell RS906 acoustic tracking system, Motorola Mini-Ranger III surface tracking system, Doppler submersible tracking system, and Trimble 10X LORAN/GPS surface navigation system. A submenu for each device selected configures the serial port parameters
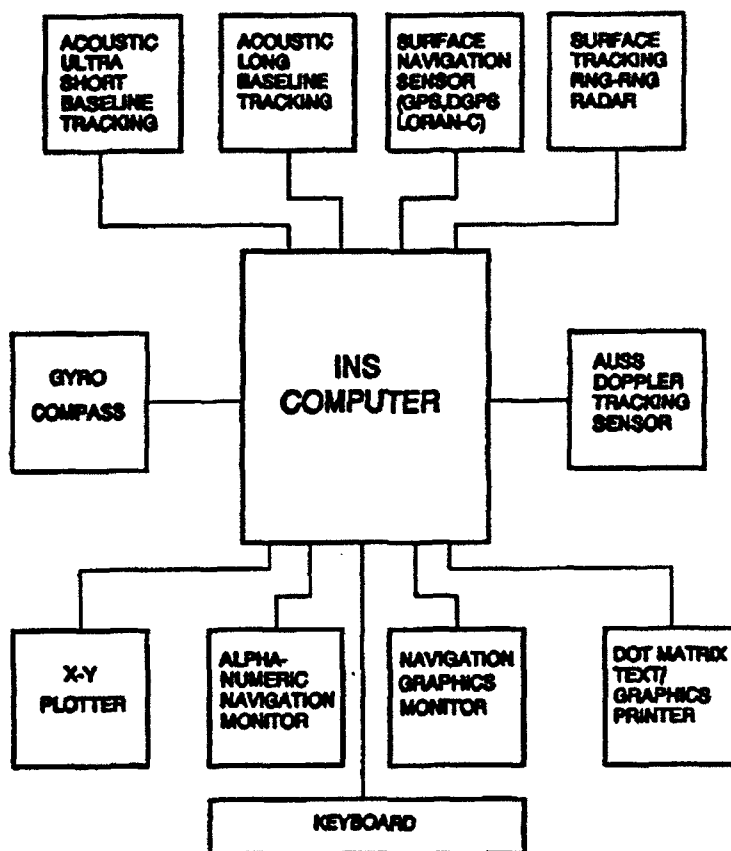
Figure 16. Seatrac INS block diagram.

Figure 17. Opening menu of the Seatrac navigation configuration program.

for baud rate, word length, stop bits, and parity. System units determine whether calculations and subsequent data output will be displayed in feet, yards, meters, or miles. Seatrac supports three coordinate conversion projections. The projection algorithms map spherical geodetic positions onto an X-Y plane suitable for plotting. Projections supported are Lambert conic conformal, universal transverse Mercator, and oblique transverse Mercator. All data stored on magnetic media are time-ticked using the computer's internal clock source or an external clock source such as an IRIG-A device. Coordinate positions are displayed as geodetic (latitude/longitude), X-Y, or northings and eastings. X-Y and northings and eastings are computed from a reference location specified in the PROJECTION submenu. Monitors supported include monochrome, color graphics adapter (CGA), and extended graphics adapter (EGA) displays. Device driver interfaces for printers and plotters are custom configured by Seaquest. Only printers and plotters specified at time of order are selecta'.e from the printer and plotter menu selections. Selecting the PRINT option from the above menu will allow the system configuration to be printed to the system printer. Appendix A is a collection of the various menus used within the Seatrac configuration program. Below each of the menus is a brief description of the menu and the data to be entered or displayed.

Once the Seatrac system has been configured, and the hardware key has been attached to the LPT1 printer port, the main navigation program can be executed. The program requires an initial geodetic position estimate to be entered into the opening program menu. Figure 18 shows the menu contents. This estimate should be within a few miles of the geodetic latitude and longitude position entered under the projection definition of the configuration utility. Selecting NO from the pop-down TRY ANOTHER? menu will position the program to the main surface navigation and underwater tracking data screen. At this time, the graphics screen should display a border with a default color and scale in the upper right-hand corner.

```
┌──────────────────┐
│ Try Another?     │
├──────────────────┤
│ No               │
│ Yes              │
└──────────────────┘
```

```
┌────────────────────────────────────────┐
│   Enter An Initial Position Estimate    │
├────────────────────────────────────────┤
│   Latitude     00°  00'  00.00"  N      │
│   Longitude    000° 00'  00.00"  E      │
│                                         │
│   Northings         -12574913           │
│   Eastings          42817181            │
└────────────────────────────────────────┘
```

Figure 18. Seatrack navigation program opening menu.

The main navigation alphanumeric screen is divided into three active regions. The left region displays surface navigation data. The right region displays submersible tracking data. The middle region consists of a series of pop-up menus for customizing the navigation program and activating/deactivating sensors, program parameters, and data calculations. The three regions are shown in figure 19. Detail of the many sublevels of menus available will not be discussed at this time. See appendix A for examples of the various nested sublevel menus. Each figure in appendix A was captured from within the operating program and is included to give the reader a general description of the program elements.

SURFACE NAVIGATION PORTAL   **MENU PORTAL**   **UNDERWATER TRACKING PORTAL**

```
                            SEATRACK
                            AAAAAAAA
Position                                      Position

                            ┌────────┐
                            │MISSION │
COG              true       │OP_AREA │        COG              true
HDG                         │SETUP   │        HDG
                            │DEVICES │
SOG              kts        │NAVAIDS │        SOG              kts
SPD                         │RATES   │        SPD
                            │MISC    │
Vector To                   │EXIT    │        Vector To
Range                       └────────┘        Range
Bearing                                       Bearing
TTG                                           TTG

Offset                                        Offset
Closing Rate                                  Closing Rate
Made Good                                     Made Good

                                              Altitude
Bottom Depth                                  Depth
            14:29:51
```
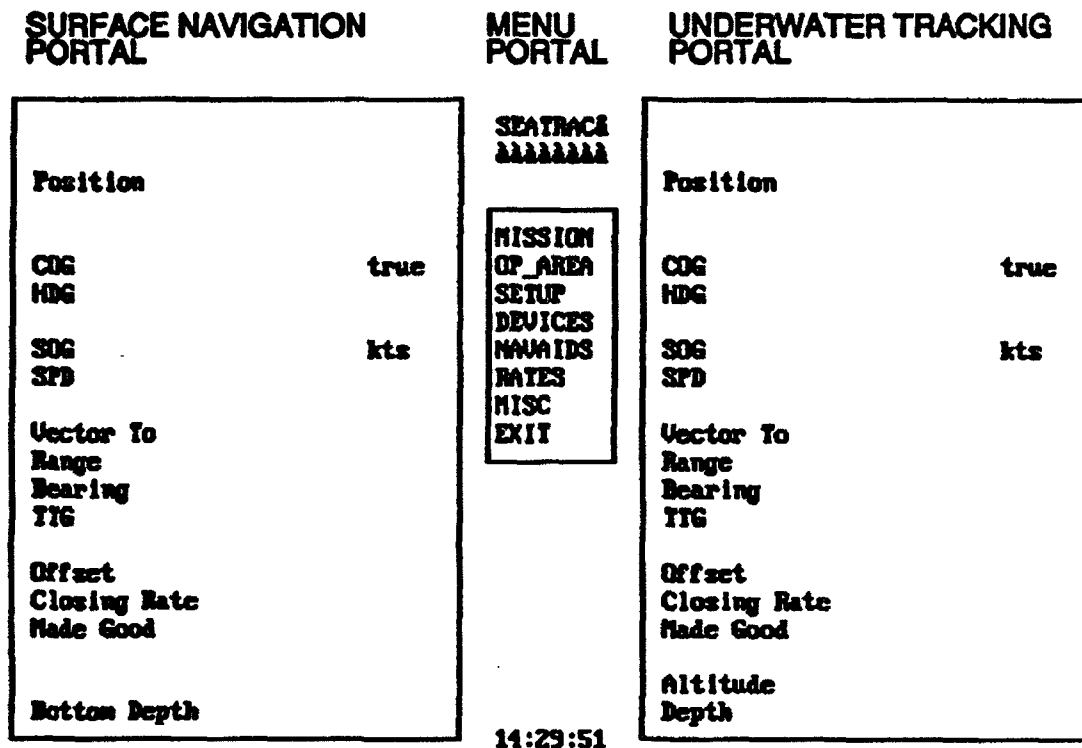
Figure 19. Seatrack INS alphanumeric screen.

Mission planning is an important aspect for successful use of the Seatrac program. The user should have an in-depth knowledge of mission scenarios before attempting to set up program elements from within the pop-up menus of the main navigation menu. As a minimum, before the program will receive data from external sensors, their interface must be activated and assigned a priority from one to three. This is done by selecting DEVICES from the main navigation screen. A submenu will prompt for vessel or ROV (remotely operated vehicle) devices. Selecting one or both of the options available will allow the user to activate the sensors attached to the system. Once the program has determined that good data are being received, plotting of vessel and/or ROV positions will be displayed on the graphics monitor. Numerical data of vessel and/or ROV position will be displayed on the alphanumeric monitor. In general, the remaining pop-up submenus available from the main navigation screen are used to

27

configure the program for specific mission scenarios or customize displays to suit the user's need. Once the applicable submenus have been configured by the user, the MISSION submenu should be selected. The SAVE option should be selected to write the system configuration to a retrievable file on the system storage media.

The advantage of the Seatrac system, and in general any true integrated navigation and tracking system, is that it allows a graphical display of surface vessel and ROV position on one monitor. The operator can determine very quickly the relative position between a surface vessel and an ROV. In the specific case of AUSS, this becomes vital for reliable communication between the support vessel and the ROV via the acoustic link. The surface ship must stay within specific radius limits of the ROV to reduce the possibility of unwanted communications errors. Errors in acoustic link telemetry data can mask targets detected by vehicle sensors, thus reducing vehicle search performance

The ability to mark surface vessel and ROV positions on the fly is an important feature of the Seatrac system. A successfully prosecuted target by AUSS can be marked while the ROV hovers above the target. Marked targets are displayed on the graphics screen and stored in a position table using the keyboard F10 key. Recorded positions can be converted to geodetic coordinates for historical purposes or for use by other search and recovery assets at later times. Figures 19 and 20 show typical graphics and text output screens available with the Seatrac system.
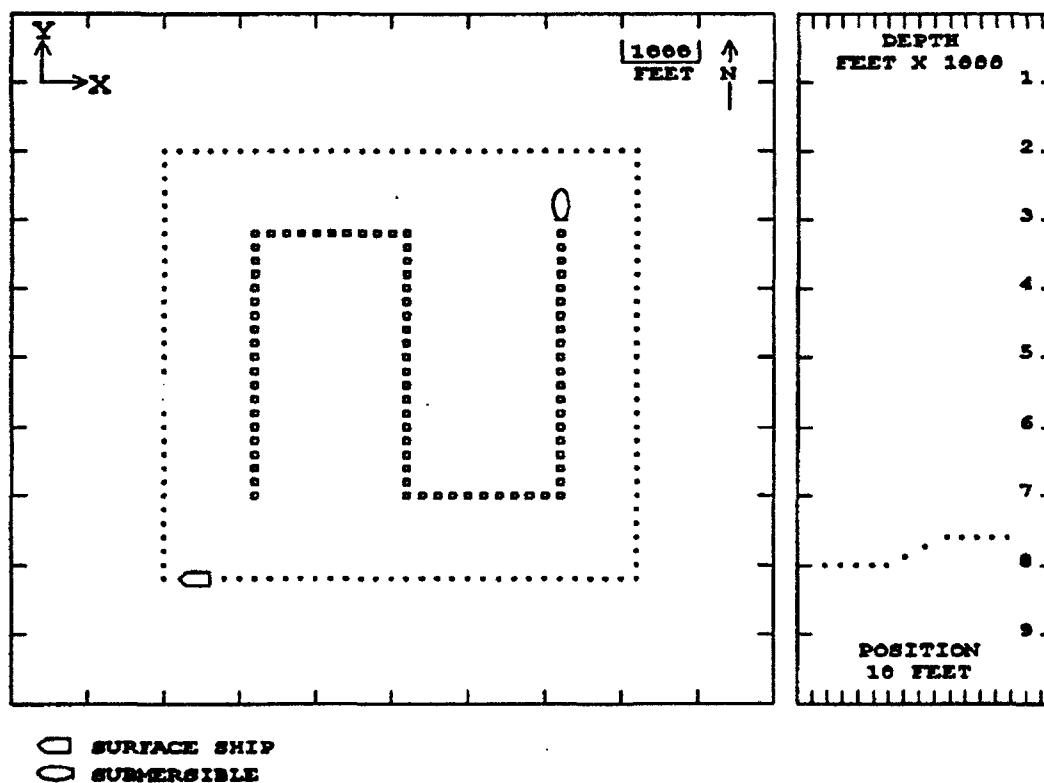
Figure 20. Seatrack INS graphics screen.

Seatrac User Interface

The Seatrac software was developed around a user-friendly interface, consisting of a series of pop-up menus for system configuration and data input. An on-line help system is also available for many of the menus to refresh memory without having to search technical documentation. Invoking the help system discloses information about the current alphanumeric screen data. Figures 21 and 22 show typical help menus available in the system software. If additional information about a specific topic is required, it can be found in the software documentation manual written by Seaquest Associates. Proficiency in using this system can be gained with as little as 6 to 8 hours of instruction. This estimate assumes that the operator is already knowledgeable with navigation and acoustic tracking topics.

The information presented on data screens is categorized by related parameters that require little or no additional information to interpret. Data input into the system improperly or out of range is met with pop-up menus notifying the operator of an error. If external sensor data are invalid or nonexistent, system error messages are displayed at the bottom of the alphanumeric display.

External Sensors And Interfaces

Many commercial aids to surface navigation and underwater tracking systems are available for use with the Seatrac system. The specific devices used by AUSS for surface navigation and/or tracking include the Motorola Mini-Ranger III range-range radar system, Trimble 10X LORAN-C/GPS navigation receiver, and Honeywell RS906 acoustic tracking system (LBL and USBL tracking). Submersible tracking sensors for the Seatrac include the Honeywell RS906 and an in-house developed system that reports X and Y position of the submersible based upon Doppler coordinates received from the AUSS vehicle via the acoustic link. The Doppler X and Y positions are reported relative to a known location of the submersible at deployment time or by acoustic tracking methods while the vehicle is in the hover mode. This custom interface was specified by NRaD and developed by Seaquest. These sensors, as a minimum, have enabled AUSS program at-sea testing to be carried out with successful results.

Hardware interfaces between the Seatrac computer and external sensors is done with a Digi-Com 8i eight-channel serial I/0. This hardware meets the RS232 EIA specification for serial communications. Each of the eight channels of the Digi-Com 8i can be independently configured for baud rate, word length, number of stop bits, and parity. This is done for the user in the configuration utility when the sensors are selected. Seatrac also supports a parallel interface for connecting a ship's gyrocompass. Word length is typically 8 bits with hardware handshaking to control data flow.

SEATRAC

Position

MISSION
OP_AREA

COG   true   COG   true

H

This is the main navigation screen. In the left portal is the
S Vessel information. In the right portal is the Remote vehicle
S information. The menu in the center is the main menu of SEATRAC.

U   To select a menu option, move the highlight bar to the desired
R option and press the enter key; or just type the first letter of the
B desired option. An overview of the options on the main menu follows
T on the next page.

                                                            Page 1 of 2
O

Closing Rate   Closing Rate
Made Good   Made Good

                                          Altitude
Bottom Depth   Depth

                        13:28:29

SEATRAC

P MISSION: load, save, print mission files.
   OP_AREA: Set up or change information about the area of
            operation. This includes blocks, tracks, waypoints
C   and positions.
H SETUP: Set up information for the color graphics display,
            plotter, and relay closures.
S DEVICES: Set up information for each positoning device and all
S   other miscellaneous devices that require setup. The
            Vessel and Remote device screens are used to turn devices
U   on and off and to select the priority of each device.
R NAVAIDS: Set up information to begin waypoint navigation, vectoring
B   to a position, and making good along a track.
T RATES: To set data recording rates for logging of data to disk,
            plotter, and printer. Turn ON/OFF data logging to disk,
O   plotter, and printer. To insert a new data disk, or start
C   a new plot. To set up relay closure rates.
M MISC: Heading Source and other miscellaneous switches.
   EXIT: Exit SEATRAC.
                                                            Page 2 of 2
B
                        14:20:03

Figure 21. Seatrac main navigation screen help menus.

30

```
The function key assignments on your machine are:

ESCAPE          Esc             Backup to previous level and save all
                                changes.
EXIT            Alt F10         Not Used
CANCEL          F7              Cancel markings or edit changes.
BACKSPACE       Backspace       Delete the character to the left of
                                the cursor.
INSERT          Ins             Insert a new item.
DELETE          Del             Delete an item.
MODIFY          F3              Rename/modify/edit the item.
SELECT          Enter           Accept information entered or select
                                the item.
HELP            F1              Provide on-line help.
MARK            F5              Toggle marking for current item.
CYCLE           Tab             Cycle through menus or screens.
MODE            F9              Change Modes.
UP              Up arrow        Move up one line.
DOWN            Down arrow      Move down one line.
LEFT            Left arrow      Move left one position.
RIGHT           Right arrow     Move right one position
SPECIAL UP      Ctrl PgUp       Move to the very beginning.
SPECIAL DOWN    Ctrl PgDn       Move to the very end.
```

Figure 22. Seatrac function key assignment help menu.

AUSS INTEGRATED NAVIGATION SYSTEM (AINS)

AINS Hardware Description

AINS currently runs on an Intel 80386-based PC-compatible computer. An 80387 math coprocessor is also used. Adapter cards installed in the system include two serial ports (COM1 and COM2), SDC-36015 six-channel synchro-to-digital card made by ILC Data Device Corporation, Ethernet adapter, EGA graphics card, and a Number Nine Corporation SGTPlus graphics adapter. The EGA graphics card is for displaying text and need only be connected to an EGA-compatible monitor. The SGTPlus graphics card is for displaying graphic positional plots and must be attached to a multisync VGA display. The Ethernet adapter is used to access a Novell Netware server on which the AINS program and all of its associated data files are stored. The remaining adapters are used for external sensor interfaces and will be discussed later. Figure 23 shows the complete system.
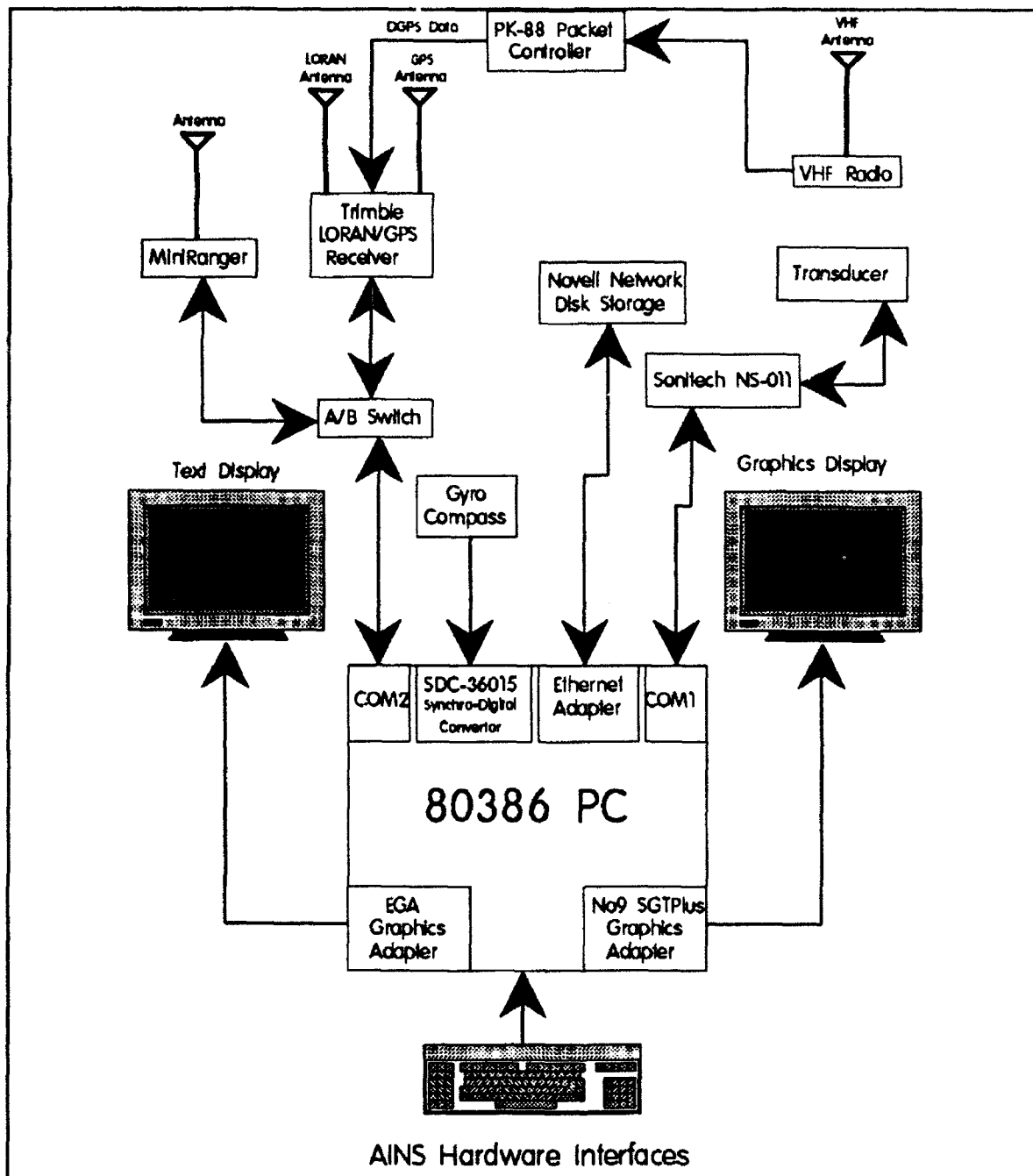
Figure 23. AINS hardware interfaces.

The following list sums up the system requirements:

- An IBM PC/KT/AT/386/486 or 100-percent compatible computer (386 or better recommended). If an 80387 is present, it will be used; if not, it will be emulated in software.

- Two serial ports (COM1 and COM2).

- 640 k RAM.

- Hard drive strongly recommended (can be run off floppy drives or network drives).

- MS-DOS or PC-DOS 3.0 or later.

- VGA or EGA graphics card and suitable display.

- Number Nine Computer Corporation's PEPPER SGTPlus graphics card.

- VGA display for SGTPlus graphics card.

- Ethernet adapter for using network drives.

- ILC Data Device Corporation's SDC-36015 Synchro-Digital Convertor if using an external heading source.

AINS Software Description

AINS is a software utility for surface and subsurface vessel tracking. AINS provides the following:

- Surface vessel can be tracked by GPS, DPGS, LORAN, Mini-Ranger III, and LBL.

- Subsurface vessel can be tracked by passive, fish-cycle, and relay LBL methods. Separate displays; one for tracking graphics and one for text status.

AINS is user-configurable by editing a text file before execution. All incoming raw ASCII data are logged starting with the data file AINSDATA.000. After about 16 k of data are written, the extension (.000) will increment by one.

The AINS package contains the following files:

AINS/AINS.CFG	Configuration file for AIN/AINS/AINS.EXE
AINS/AINS HIP	AINS help file
AINS/AINS.NDK	Index file for the help system
AINS/NS011.CFG	Configuration file for the NS-011
AINS/XPONPOS	Binary file containing the locations of the transponders
AINS/FIRSTFIK	Text file containing a first fix for the LBL algorithms
AINS/TURNARND	Text file containing the turnaround times for the transponders

AINS/12KSITE	Binary overlay file
AINS/MISSIONB	"
AINS/BAJA	"
AINS/DROPPNTS	"
AINS/OCNSIDE	"
AINS/OLDS	"
AINS/OP3703	"
AINS/PTLOMA	"
AINS/LAJOLLA	"
AINS/TARGETS	"
AINS/MAKEFILE	Makefile for Microsoft C v. 6.00
AINS/NS011.C	Source code file for AINS
AINS/MREAD.C	"
AINS/RNGRNG.C	"
AINS/NO9PLOT.C	"
AINS/AINS.C	"
AINS/GYRO.C	"
AINS/HYPERBOL.C	"
AINS/AUSSSURF.C	"
AINS/AUSSLBL..C	"
AINS/RS232INT.C	"
AINS/NNIOS/LNNIOS.LIB	NNIOS function library for large memory model
AINS/NNIOS/FONTS.H	NNIOS header file
AINS/NNIOS/NNIOS.H	"
AINS/NNIOS/NNIOS.INC	"
AINS/NNIOS/NNIOSLIB.H	"
AINS/NNIOS/TINNIOS.H	"
AINS/SERIAL/NSPL.LIB	NRaD Serial Port Library for large memory model
AINS/SERIAL/SERIAL.H	NSPL header file

34

AINS/UTILITY/ASCTOBIN.EXE	Converts ASCII files to binary
AINS/UTILITY/BINTOASC.EXE	Converts binary files to ASCII
AINS/UTILITY/GENINDEX.EXE	Generates a new help index file
AINS/UTILITY/NNRESET.EXE	Resets the Number Nine graphics card
AINS/UTILITY/NNIOS.NEW	NNIOS.SYS for newer SGTPlus cards
AINS/UTILITY/NNIOS.OLD	NNIOS.SYS for older SGT cards
AINS/UTILITY/NNVER.EXE	Prints information about your Number Nine graphics card
AINS/WINBOSS/LWIN.LIB	Text windowing library for large memory model
AINS/WINBOSS/WINBOSS.EXT	Text windowing header file
AINS/WINBOSS/WINBOSS.FNS	"
AINS/WINBOSS/WINBOSS.H	"

Setting Up the AINS Program

To fully use all features of AINS, the following steps must be performed before use:

(1)   Edit the TURNARND file in the \AINS directory:

```
9 2
1 3
2 3
3 3
4 3
5 3
6 3
7 3
8 3
9 8
```

The first pair of numbers in the file represents the number of rows and columns of data in the file. In this example, there are nine rows of data and two columns of data. Therefore, the first two numbers in the file are 9 2. This format is used for all AINS data files, whether binary or ASCII. The next eight rows represent the eight transponder channels and their corresponding turnaround times in milliseconds. The last pair of numbers represent the subsurface platform and its turnaround time.

(2) Edit the XPONPOS file in the \AINS directory to reflect the Lambert coordinates of your bottom-mounted transponders. The XPONPOS is a binary file and must be converted to ASCII for editing. Use the BINTOASC.EXE

35

utility located in the \AINS\UTILITY directory to do this. What follows is the converted XPONPOS file:

8 3

3.739800435681806E+05 −1.323244229042014E+05 3.825318435689650E+03

3.774882142331403E+05 −1.323183294249735E+05 3.796387357058210E+03

3.774899209078814E+05 −1.357538085673531E+05 3.868228818263804E+03

3.773497083250820E+05 −1.356552004283492E+05 3.870106816019183E+03

3.739568863024194E+05 −1.357352398594653E+05 3.866910488454372E+03

3.739808335681806E+05 −1.324442029042014E+05 3.828918435689650E+03

3.774462242331404E+05 −1.324016694249735E+05 3.801817357058210E+03

3.774759109078814E+05 −1.357933885673531E+05 3.872718818263804E+03

The first pair of numbers, once again, denotes the rows and columns of data in the file. The rest of the data in the file indicate the Lambert coordinates (x,y,z) of the bottom-mounted transponders. Table 2 shows the frequencies assigned to each of the eight channels. If these frequencies need to be changed, one must edit the user array in the AUSSLBL.C module and recompile (see next section). Once the editing is complete, use the ASCTOBIN.EXE utility located in the \AINS\UTILITY directory to convert the file back to binary.

Table 2. Frequencies assigned to channels.

CHANNEL	FREQUENCY (Hz)
1	11,000
2	11,500
3	12,000
4	12,500
5	15,000
6	15,500
7	16,000
8	16,500

(3) Make sure NNIOS.SYS is installed in your CONFIG.SYS. If not, two different NNIOS.SYS files are located in the .\AINS\UTILITY directory. NNIOS.OLD is for SGT cards and NNIOS.NEW is for SGTPlus cards. Rename the appropriate file and install in your CONFIG.SYS.

(4) Edit the FIRSTFIX file in the \AINS directory. This ASCII file contains an (x,y) position in Lambert coordinates that the positioning algorithms use as a first guess. This data point should be in the vicinity of your operating area. The FIRSTFIX file:

$$375720.42 \quad -133932.39$$

(5) Edit the AINS.CFG and NS011.CFG to suit your preferences.

(6) Run the AINS.EXE program by typing AINS from within the \AINS directory.

(7) Set up external navigation sensors depending upon what type of navigation (surface or subsurface) you are using. Press the 't' key from within AINS and select the navigation type:

GPS/DGPS—Set up the Trimble unit for GPS or DGPS (whichever you prefer). AINS will automatically display on the status screen whether the data coming from the Trimble are GPS or DGPS. Make sure the code for the OUT1 channel is set correctly. This is done by pressing Select (from the top level) two times, then Code, and then Out1 (refer to the Trimble 10X manual for more details). Next, enter the following code:

$$04100000500$$

LORAN—Nothing need be done to the Trimble unit. The status screen will change to reflect your choice.

Mini-Ranger III—The status screen will change to reflect your choice.

LBL (surface)—Initialize the NS-011 by pressing Alt-F2 from within AINS. This will send the contents of the file NS011.CFG to the NS-011. To enable subsurface tracking, press the 'P' key.

The AINS configuration file, AINS.CFG, is fairly self-explanatory as it is commented. Additional comments are bracketed.

```
# AINS.CFG—config file for the AINS navigation program
# Created on 5/21/92 by C. Geurin
#
# Screen Width (in)                                          9.7
# Screen Height (in)                                         7.7
# Use Mouse Y/N [Future capability, not implemented yet]        Y
# GPS PDOP threshold                                        10.0
# Lambert Zone                                                 6
# Offset from Zulu Time (Greenwich)   -7.0
# Icon Size S/M/L [Size of the ship and ROV icons]             M
# Colors and their values:
# BLACK                                                       00
# BLUE                                                        01
# GREEN                                                       02
# CYAN                                                        03
# RED                                                         04
# MAGENTA                                                     05
# BROWN                                                       06
# LIGHT_GRAY                                                  07
# DARK_GRAY                                                   08
# LIGHT_BLUE                                                  09
# LIGHT_GREEN                                                 10
# LIGHT_CYAN                                                  11
# LIGHT_RED                                                   12
# LIGHT_MAGENTA                                               13
# YELLOW                                                      14
# WHITE                                                       15
#
# ROV Color                                                   12
# Ship Color                                                  15
# Overlay file names.
# Maximum of 20.
# Last entry must be followed by an entry of 0.
ptloma
baja
op3703
droppnts
targets
12ksite
olds
```

```
wtchcirc
oparea.001
oparea.002
oparea.003
oparea.004
oparea.005
oparea.006
oparea.007
oparea.008
oparea.009
oparea.010
oparea.011
oparea.012
0
# Extra points file names
# Maximum of 20.
# Last entry must be followed by an entry of 0.
pier
pointx
buoy1
lblbuoy1
lblbuoy2
lblbuoy3
lblbuoy4
sparept0
sparept1
sparept2
sparept3
sparept4
sparept5
sparept6
sparept7
sparept8
sparept9
0
```

The configuration file for the NS-011, NS011.CFG, is a list of commands that is sent to the NS-011. The configuration file is sent to the NS-011 whenever Alt-F2 is pressed from within the AINS program. Please refer to the SonaTech NS-011 manual for a description of the available commands. A listing of NS011.CFG follows:

```
cc
rs da
as  a
av
av  4
na
td  0
ar  a  7.0  13.0  13.5  14.5  15.0
ar  b  15.5  16.0
qc
sq  a  15  9000  10
rl  20
rr  4
rt  4
pt
tt
pw  0
ir  10
lo  200
sp  4
si
```

AINS Graphic Overlay Files

The overlay files used by AINS are binary files that follow the format of the XPONPOS files except the Lambert coordinates in the file are only specified in two dimensions. To look at or edit the overlay files, they must first be converted to ASCII by using the BINTOASC.EXE program in the .\AINS\UTILITY directory. The overlay file OLDS has been converted and a portion of the resulting text file is presented below. Again, the first pair of numbers indicates the number of rows and columns of numbers in the data file. The numbers following the first pair are Lambert coordinates in the form of X-Y.

```
89 2

3.754840000000000E+05  -1.340380000000000E+05

3.754850000000000E+05  -1.340370000000000E+05

3.754860000000000E+05  -1.340360000000000E+05

3.754870000000000E+05  -1.340350000000000E+05
```

AINS User Interface

The AINS user interface consists of a graphics display on which positional plots are displayed and a text display where the system status is displayed. The text display is also where the user interacts with AINS. As the initial navigation mode is GPS, the user will see the screen shown in figure 24 upon initial start-up of AINS.

The AINS text display is based on a system of "active windows." That is, at any given time, only the top (completely visible) window is the active one. The AINS program has three windows: status, data entry, and help. Figure 24 shows the status screen. The data entry screen is behind the status screen.

Figure 24. AINS status screen.

Pressing F1 will pull up the help screen, which lists all available commands:

A	Toggle active/passive option for subsurface tracking.
b	Set baud rate of COM1 and COM2.
c	Specify the center of the graphics screen by manually entering coordinates.
C	Specify the center of the graphics screen from coordinates in an ASCII file.
d	Disable/enable individual transponders.
f	Center the graphics screen on the ship (will not change width).
F	Center the graphics screen on the ROV (will not change width).
h	Select fish-cycle response channel.
m	Select Mini-Ranger III stations.
M	Toggle master/slave option for subsurface tracking.

o	Enable overlay files specified in AINS.CFG.
p	Set number of displayable past track points.
P	Toggle the ROV Enable flag.
q	Quit.
r	Toggle range-arc option.
s	Force ship position to equal the graphics screen center.
S	Force ROV position to equal the graphics screen center.
t	Type of surface ship navigation (LBL, LORAN, Mini-Ranger III, GPS).
T	Type of subsurface ROV navigation (transponder or responder).
u	Update the screens without any changes.
v	Change the system sound velocity.
w	Set the absolute width of the graphics screen (in yards).
W	Make a watch circle.
y	Correct a LORAN cycle slip.
Y	Toggle the state of the auto-cycle flag.
z	Manually set the ROV depth, or have AINS calculate it.
Z	Change depth of ship's hydrophone.
← ↑ ↓ →	Move the graphics window 1/10 of the current screenwidth.
Shift ← ↑ ↓ →	Move the graphics window 5/10 of the current screenwidth.
F1	Display the help screen.
F2	Enter the NS-011 "chat mode" (a terminal session with the NS-011).
ALT-F2	Initialize the NS-011, and set its clock to match the PC's clock.
F10	Clear all past tracks.

When the user enters a command that requires additional data, the Data Entry window becomes active. Figure 25 shows an example of pressing the "d" key:

By pressing the "t" key, the user can select the type of surface navigation. Figure 26 shows the Mini-Ranger III status screen.

Figure 27 shows the LORAN-C status screen and figure 28 shows the LBL status screen.

Pressing F2 will allow the operator to manually send commands to the SonaTech NS-011. Pressing F2 again will exit the NS-011 "chat mode." Figure 29 shows the "chat mode."

```
━━━━━━━━━━━━━━━━━━━━ Data Entry ━━━━━━━━━━━━━━━━━━━
  13        0    oparea.006
  14        0    oparea.007
  15        0    oparea.008
  16        0    oparea.009
  17        0    oparea.010
  18        0    oparea.011
  19        0    oparea.012
Toggle the enable flags on which file numbers:
Current center 565746.5  65604.4 yards; new x? y?
Xpon Turnarnd(ns)
  ─────────────
  1        3.0
  2        3.0
  3        3.0
  4        3.0
  5        3.0
  6        3.0
  7        3.0
  8        3.0
  9        8.0
Negative means Disabled; last one is platform itself.
Toggle the enable flags on which transponders:
```

Figure 25. AINS data entry screen.

```
━━━━━━━━━━━━━━━━━━━━━━ Status ━━━━━━━━━━━━━━━━━━━━━
NAV MODE: MiniRanger ACTIVE MASTER        MiniRanger INFO:
                                          CODE RANGE
CENTER                 WIDTH                 0      0
(565746.5, 65604.4)  50000.0                 0      0

DIST TO CENTER FROM:   RAB TO CENTER FROM:
SHIP                        SHIP
(   0.0,   0.0)        RNG     0.0
                       BRNG    189

TIME          SPEED         LAST FIX
  0 13:43:30    0.0 kt.      0: 0: 0
TO CENTER   TIME TO GO
  0.0 mi.       0 min.

                    <Press F1 for Help>
─────────────────────────────────────────────────
  0 MiniRanger
  1 GPS
  2 LORAN
  3 LBL
Choose:
0
```

Figure 26. Mini-Ranger III status screen.

43

```
╔══════════════════════════ Status ══════════════════════════╗
║ NAV MODE: LORAN-C ACTIVE MASTER          LORAN-C INFO:       ║
║                                             TDX      TDY     ║
║ CENTER              WIDTH                   0.00     0.00    ║
║ (565746.5, 65604.4) 50000.0                                 ║
║                                                             ║
║ DIST TO CENTER FROM:    R&B TO CENTER FROM:                  ║
║ SHIP                        SHIP                             ║
║ (  0.0,   0.0)          RNG    0.0                           ║
║                        BRNG    180                           ║
║                                                             ║
║ TIME          SPEED          LAST FIX                        ║
║  0 23:59:60    0.0 kt.        0: 0: 0                        ║
║ TO CENTER   TIME TO GO                                       ║
║  0.0 mi.      0 min.                                         ║
║                                                             ║
║                    <Press F1 for Help>                       ║
╟─────────────────────────────────────────────────────────────╢
║  0 MiniRanger                                               ║
║  1 GPS                                                      ║
║  2 LORAN                                                    ║
║  3 LBL                                                      ║
║ Choose:                                                    ║
║ 2                                                          ║
╚═════════════════════════════════════════════════════════════╝
```

Figure 27. LORAN-C status screen.

```
╔══════════════════════════ Status ══════════════════════════╗
║ NAV MODE: LBL ACTIVE MASTER              LBL INFO:           ║
║                                          XPONDERS   ERROR    ║
║ CENTER              WIDTH                   0         0.00 rms║
║ (565746.5, 65604.4) 50000.0                                 ║
║                                                             ║
║ DIST TO CENTER FROM:    R&B TO CENTER FROM:                  ║
║ SHIP                        SHIP                             ║
║ (  0.0,   0.0)          RNG    0.0                           ║
║                        BRNG    180                           ║
║                                                             ║
║ TIME          SPEED          LAST FIX                        ║
║  0 23:59:60    0.0 kt.        0: 0: 0                        ║
║ TO CENTER   TIME TO GO                                       ║
║  0.0 mi.      0 min.                                         ║
║                                                             ║
║                    <Press F1 for Help>                       ║
╟─────────────────────────────────────────────────────────────╢
║  0 MiniRanger                                               ║
║  1 GPS                                                      ║
║  2 LORAN                                                    ║
║  3 LBL                                                      ║
║ Choose:                                                    ║
║ 3                                                          ║
╚═════════════════════════════════════════════════════════════╝
```

Figure 28. LBL status screen.

44

```
┌─────────────────────────────────────────────────────────────┐
│├──────────────────────── Data Entry ───────────────────────┤│
││First save will be to file ainsdata.000.                    ││
││In NS-011 Chat Mode, Press F2 to exit.                      ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
││                                                            ││
│└────────────────────────────────────────────────────────────┘
└─────────────────────────────────────────────────────────────┘
```
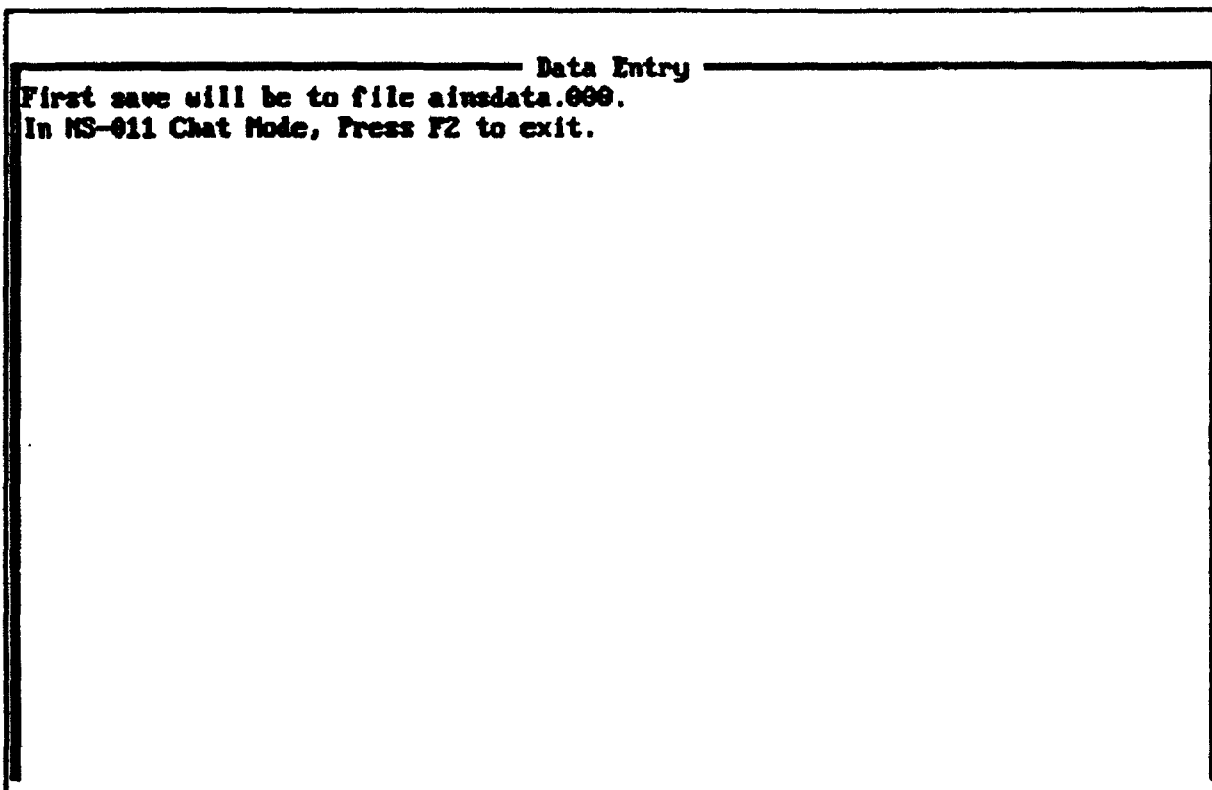
Figure 29. SonaTech NS-O11 "chat mode."

When doing serial I/O, AINS will eventually time out if nothing has been received from the serial port. Figure 30 shows an example of a serial I/O error. The error messages will automatically disappear when the problem is remedied.

External Sensors And Interfaces

A SonaTech NS-011 is connected to the PC's first serial port (COM1), and a transducer is connected to the NS-011. The NS-011 is used for LBL underwater navigation.

The gyrocompass (for external heading input) is connected via five twisted wires (R1, R2, S1, S2, S3) to the SDC-36015 Synchro-Digital Convertor in the PC. The SDC-36015 converts the synchro information transmitted by the gyrocompass to digital information that can be read off the adapter card by the PC.

Attached to the second serial (COM2) port on the PC is an A/B switch. Using this switch, the operator can switch between LORAN/GPS/DGPS and Mini-Ranger III for surface navigation. The Mini-Ranger III, LORAN, GPS, and DGPS receivers each require a separate antenna. For the Trimble GPS receiver to use the DGPS corrections transmitted from a shore station, a VHF radio connected to a PK-88 Packet Controller must be attached to the Trimble receiver. Figure 23 shows all external sensors and interfaces.

```
┌─────────────────────────── Status ───────────────────────────┐
│ NAU MODE: GPS ACTIVE MASTER          GPS INFO:                │
│                                      SV    PDOP                │
│ CENTER              WIDTH            0    0.0                  │
│ (565746.5, 65604.4) 50000.0         0                         │
│                                      0                         │
│ DIST TO CENTER FROM:  RAB TO CENTER FROM:  0                   │
│ SHIP                    SHIP              DATUM:               │
│ (  0.0,   0.0)          RNG   0.0         WGS-84               │
│                         BRNG  100                              │
│                                                               │
│ TIME          SPEED          LAST FIX                         │
│  0  0: 0: 0    0.0 kt.        0: 0: 0                          │
│ TO CENTER  TIME TO GO                                          │
│  0.0 mi.      0 min.                                           │
│            Nothing from COM2 for non-acoustic ship nav.       │
│                   <Press F1 for Help>                         │
└───────────────────────────────────────────────────────────────┘
```

Figure 30. Example of serial I/0 error message.

The following list sums up external sensor requirements:

- SonaTech NS-011 Acoustic Transceiver attached to COM1 via a null-modem cable (for LBL acoustic tracking).

- An A/B switch box connected to COM2.

- Trimble LORAN/GPS 10X receiver attached to the A/B switch.

- Mini-Ranger III attached to the A/B switch.

- A gyrocompass that transmits heading information in a 110-V synchro format connected to the SDC-36015.

UNDERWATER ACOUSTIC TRANSPONDER NETWORK CALIBRATION

SYSTEM DESCRIPTION AND CAPABILITIES

LBL acoustic tracking of a surface vessel or submersible requires the installation of a network of underwater transponders. Positional information is determined by measuring ranges between a surface ship and the calibrated locations of the transponders moored to the sea floor. A microcomputer using information defining the relative

46

positions of all transponders can perform geometric calculations on range data to determine position within the network. For three-dimensional tracking of a submersible (X,Y,Z Cartesian coordinate system), slant ranges from a minimum of three transponders must be determined. Additional transponders are generally deployed for system redundancy. This significantly increases system tracking ability. Two-dimensional tracking can be performed with returns from a minimum of two transponders; however, two ranges produce two positional fixes. The ambiguity of which side of the baseline the true fix lies must be resolved before reliable tracking can be produced. The accuracy of a LBL tracking system is determined primarily by how well the relative positions between transponders are known. The transponder network calibration algorithms developed by NRaD determine relative transponder positions. Additionally, when surface navigation data are available, relative transponder positions can be fixed to geodetic positions in latitude and longitude or Lambert coordinates. The resultant transponder positions are used by the AINS software to provide surface and submersible tracking.

The purpose of this section is to explain the capabilities of the AUSS LBL calibration system. An in-depth discussion of the algorithms used is not presented in this report. The discussion includes an overview of the methods used and the steps necessary, once the transponders are deployed, to calibrate the network.

Figure 31 is a functional flow diagram showing the necessary steps that must be taken to determine transponder positions. Blocks indicated by rectangles represent computer programs that must be executed during the process. Blocks with rounded ends represent data files that are created by the programs. The calibration process flow is essentially from top to bottom. The transponder network calibration process is started only after the transponder field is deployed.

TRANSPONDER DEPLOYMENT

The installation of an LBL network of transponders requires some preplanning before the task can be successfully carried out. The installation represents a sizeable expenditure of time, labor, and money. The following list of criteria should be addressed before deploying transponders so as to minimize expenditures and maximize the success of the calibration procedure and subsequent LBS tracking.

- Required interrogate and respond frequencies
- Minimum acoustic source level required
- Minimum receiver sensitivity required
- Maximum deployable depth requirements
- Transponder buoyancy
- Expendable or recoverable transponders
- Ocean-bottom contour (i.e., flat, sloped, hilly, etc.)
- Deployed transponder altitude and separation

47
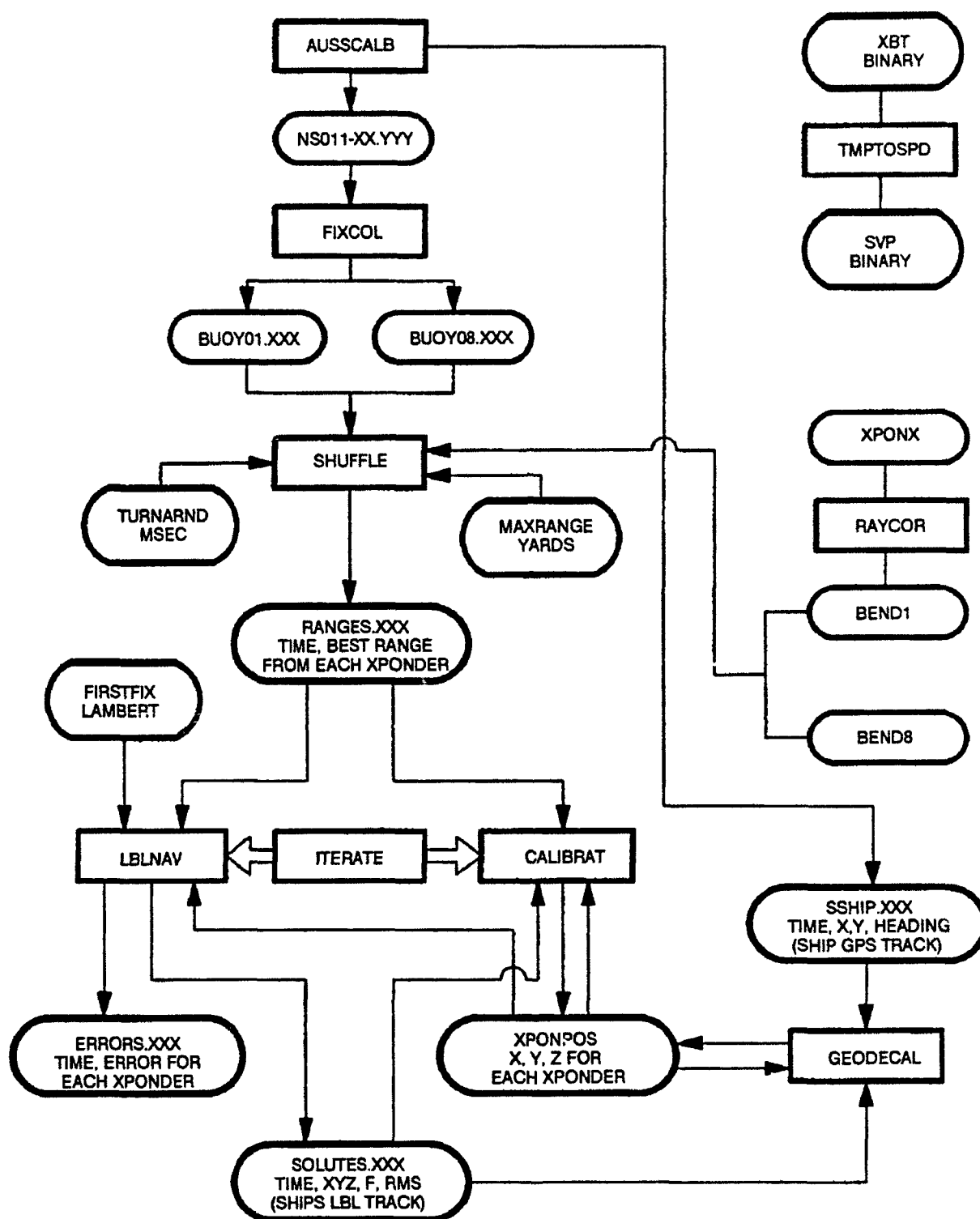
Figure 31. AUSS network calibration program functional flow diagram.

- Transponder life cycle (i.e., maximum number of transponds, battery life years)
- Transponder command codes required

During the deployment phase, the transponders are first checked to verify the proper interrogate and respond frequencies. Any command codes they respond to are also checked for proper operation. Internal batteries are monitored to verify that terminal voltages meet specifications under load before deployment. If the transponders have release mechanisms, the mechanical and electrical functions are checked before rigging.

Transponder rigging usually consists of a mooring weight, a transponder tether, and depending upon whether the transponders have buoyancy or not, a float with its tether attached to the opposite end of the transponder. A mooring weight, 50 to 60 pounds greater than the system buoyancy, should be sufficient to serve as an anchor. The length of the tether attaching the transponder to the mooring weight should be of sufficient length to allow reliable communications between a submersible and all deployed tranponders. Mooring too close to the bottom could render the transponder unusable for tracking because of acoustic shadow zones created by ray bending. An excessively long tether could adversily affect transponder position due to ocean currents. An unstable transponder position could cause excessive network calibration and LBL tracking errors.

Transponder surface deployment locations should be determined and marked on the Seatrac INS before positioning the surface ship to the drop point. The float, if necessary, and the transponder are deployed over the side approximately 100 yards from the desired drop point. As the ship transits over the drop point, the mooring weight is deployed and the transponder descends to the ocean bottom. Depending upon sea state, ship speed is generally 2 to 3 knots during this procedure. The remaining transponders of the field are deployed in the same manner.

The deployment time for an LBL network depends on the number of transponders deployed, the network size, and the speed capabilities of the surface ship. A support ship, moving from drop point to drop point at 8 knots, can deploy a four-transponder network on the corners of a 12,000-foot square in approximately 90 minutes. Speed reduction at the drop points is accounted for in this period.

When all transponders have been deployed and communications with each unit have been verified, the data collection process can be started. The software program (AUSSCALB.EXE), developed by NRaD, and associated hardware, will automatically collect calibration data. The program controls the acoustic interrogation of the LBL network and collects and stores slant range data from each deployed transponder. The interrogation repetition rate is user-selectable. Sufficient time should be allowed between interrogations to record all slant range returns.

The data collection process consists of the surface vessel moving along a designated path that takes it over each transponder, halfway between each transponder, and on a diagonal between two transponders. Slant ranges for each interrogation cycle are stored

in NS-011xx.yyy data files. These files consist of raw range data and must be filtered to remove bad data points before executing the calibration program. Filtered data are used by the calibration software routines to determine the relative positions, in X,Y,Z space, of the transponders.

LBL NETWORK DATA COLLECTION

During transponder deployment, the geodetic coordinates of the surface drop points are recorded by using the Seatrac INS marking capabilities. Geodetic drop point coordinates for each transponder must be converted to Lambert state plane coordinates using LAMNAD.EXE, a program developed at NRaD. The resulting Lambert X-Y drop points and an estimated value for the transponder depths are arranged into an ASCII data file as shown below. The first line of this file describes the data format structure (i.e., eight lines by three columns of data). Data columns 1, 2, and 3 represent Lambert X (yards), Lambert Y (yards), and Z depth (yards), respectively. The data set below represents California zone 6 Lambert coordinates.

```
8 3
5.3661520234956E+05  9.916092217164148E+04  7.925949547159338E+02
5.3662273854974E+05  1.005227934117717E+05  7.743130998766690E+02
5.3797317880782E+05  1.005076472787007E+05  7.667964246167862E+02
5.3793336250119E+05  9.915039329251628E+04  7.885219720916941E+02
5.3650548794984E+05  9.908648425211225E+04  7.902814142965642E+02
5.3654085588248E+05  1.005843533279032E+05  7.757969655592029E+02
5.3804575984193E+05  1.005518947328134E+05  7.659080483325389E+02
5.3797680250119E+05  9.902708329251628E+04  7.906419720916941E+02
```

The ASCII file must be converted to binary format using the ASCTOBIN.EXE conversion program. The ASCII file can be given any name, but the output binary file representation must be named XPONPOS. This binary file will be used by programs LBLNAV.EXE, CALIBRAT.EXE, and GEODECAL.EXE to produce relative and absolute transponder positions. The XPONPOS file is modified during an iterative process by the above-mentioned programs. The modified XPONPOS file represents the calibrated geodetic position of all transponders in the network. AINS uses the modified version of XPONPOS for surface and submersible tracking.

CALIBRATION SYSTEM HARDWARE DESCRIPTION

Transponder network calibration can be performed using the Honeywell RS906 or AINS hardware. The Honeywell RS906 is a four-channel LBL receiver. This limits the network size to four transponders for calibration purposes. AINS, on the other hand, uses the SonaTech NS-011 acoustic transceiver. The NS-011 has 32-channel acoustic

receiver capability when all receiver slots are installed. This significantly increases the possibilities for transponder network configurations. All LBL transponder networks used to support AUSS operation were calibrated using AINS hardware. The following list summarizes the necessary equipment to perform transponder network calibration. The list assumes transponders have already been deployed.

- NS-011 acoustic transceiver
- ITC 3165 transducer with baffle
- Transducer pole
- XBT temperature profile probes (optional)
- XBT temperature profile recorder (optional)
- Command code generator compatible with deployed transponders
- LORAN/GPS/Mini-Ranger III surface navigation
- 80386/80486-based personal computer with hard and floppy drives
- 80387 math coprocessor
- EGA/VGA color monitor
- 1 megabyte of extended memory
- Summa Graphics digitizing pad

All hardware can be easily installed in a 19-inch mini-rack and operated from almost any ship of opportunity. Power requirements are 110-120 VAC, 60-Hz single phase, 2 KVA.

CALIBRATION SYSTEM SOFTWARE DESCRIPTION

Several software programs make up the calibration system. The following is a list of all executable programs necessary to calibrate a transponder field consisting of four to eight DOTs.

- NS11DRIV.EXE
- AUSSCALB.EXE
- FIXSUMMA.EXE
- SHUFFLE.EXE
- LBLNAV.EXE
- CALIBRAT.EXE
- ITERATE.BAT

- GEODECAL.EXE
- TMPTOSPD.EXE (optional)
- RAYCOR.BAT (optional)

The above programs were all developed at NRaD for use on the AUSS program. All coding was done using the C programming language and compiled with the Microsoft C version 5.0 compiler. The programs have been used to calibrate several LBL transponder networks, used during AUSS development, with favorable results. The following paragraphs will explain the functional duties of the programs and their interaction and dependency with each other. The functional flow diagram, figure 31, will be used from time to time to aid in the explanation.

NS11DRIV.EXE

NS11DRIV.EXE is executed to establish serial communications between a host computer and an NS-011 acoustic transceiver via RS232-compatible ports. The program also reads a data file named NS11DRIV.INI and configures the NS-011 for specific operating parameters. A sample NS11DRIV.INI file follows. The file is created using any nondocument text editor. The first two characters of each line represent an NS-011 command. All fields after the command field represent parameters necessary for proper execution of the command. Distinct fields are delimited by spaces. The NS-011 command set is lengthy and will not be presented in this report. The entire command set and associated parameters are defined in "SonaTech Inc. NS-011 Acoustic Transceiver Operating Manual," Document Number 1736-8907L.

In general, the following NS-011 commands and parameters set up transceiver interrogate and receive frequencies, transmit acoustic pulse width and interrogation repetition rate, and receiver listening time.

```
cc
rs da
as a
av
av 4
av 8
av 12
na
td 0
ar a 7.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0
ar b 15.5 16.0 16.5
qc
sq a 15    9000 10
rl 20
rr 4
rt 4
```

```
pt
tt
pw  0
ir  10
lo  200
sp  4
```

NS11DRIV.EXE, when used as a stand-alone program, writes raw ASCII data received from the NS-011 to NAV.xx files. When the file size reaches a maximum byte count, it is closed and a new file is opened for additional data. The "xx" in the file name is assigned a numerical value starting with "00" and is incremented by one when the file is closed and the next file is opened. The data file content consists of two-way travel times of an acoustic pulse between a surface ship and each underwater transponder. Each travel time is marked with the corresponding respond frequency of the received acoustic pulses and the write time for the data set. When the program is used in conjunction with programs such as AUSSCALB.EXE, the NAV.xx files are not created, but instead the slant range data are fed directly into the using program for further processing. A sample NAV.xx data file is shown in appendix B.

RAYCOR.BAT

One of the first tasks to be done in establishing a calibrated LBL network is to take a water temperature profile in the area where transponders will be deployed. This procedure is necessary to determine the effects of water temperature on sound speed. Expendable bathythermograph (XBT) temperature probes are launched and descend down the water column. Surface equipment records the water temperature as the probe descends. For every data point the recorder stores, the program TMPTOSPD.EXE calculates sound velocity as a function of temperature, depth, and salinity and stores the information in an SVP (sound velocity profile) file. This file is used during the calibration process to refine slant range values which are dependent on a variable sound speed. Probes have depth capabilities that range from zero to 6000 feet.

Ranges collected by AUSSCALB.EXE and edited by FIXSUMMA.EXE do not represent straight line slant ranges. Due to the acoustic properties of sound in water, slant ranges can be represented by rays that have a slight curvature to them. As such, round-trip travel times between a surface ship transducer and an underwater transponder will be longer. This characteristic produces errors in the calibration process if not accounted for. Slant ranges are calculated by dividing round-trip travel times by a factor of two and multiplying by the speed of sound in water.

The speed of sound in water is not constant, but varies as a function of pressure (pressure is a function of water depth), temperature, and salinity. The effect of sound speed due to depth and salinity are easily accounted for, but water temperature is unpredictable and can vary significantly at shallow depths from day to day in the same area. Calibrating a network for the best possible accuracy must account for the variance of sound speed in water as the wavefront propagates through the water. Various

systems used in the past allow for a simple harmonic average sound speed when making range calculations. Programs have been developed to do better than using an average sound speed.

TMPTOSPD.EXE, RAYCOR.BAT, and associated data files XBT, SVP, XPONX, and BEND1 through BEND8 ultimately generate coefficients of a third-degree polynomial. The polynomial is then used to generate a good approximation of sound speed as a function of range. From figure 31, the sound-speed coefficients from data files BEND1 through BEND8 can be fed to SHUFFLE.EXE to adjust range values. See the discussion of SHUFFLE.EXE below for more detail.

AUSSCALB.EXE

AUSSCALB.EXE, in conjunction with the NS-011 and surface navigation receivers, collect raw calibration data consisting of transponder slant ranges and corresponding geodetic fixes of the surface support craft. The program automatically stores up to a maximum of 24 channels of slant range data from the NS-011 to files named NS011-XX.YYY. Surface navigation data are saved to files named SSHIP.XXX. AUSSCALB. EXE creates data files using the same procedure explained earlier with NS011DRIV. EXE. The program sets up the NS-011 to autointerrogate the network at 15-second intervals and holds the receiver channels open to process returns for 8 seconds following the interrogation. These are program default time intervals and can be changed by modifying the NS-011driv.ini file. Data files NS011-XX.YYY and SSHIP-XXX are time-tagged using the realtime clock available from the NS-011.

Two display modes are supported by AUSSCALB.EXE. The range history mode displays slant range as a function of time for a selected transponder. This mode is useful when postprocessing of data will be conducted to determine transponder relative or absolute positions. The operator can determine by screen observations whether the slant range data for the selected transponder are good data (i.e., direct path data, bounce path data, or no data). The realtime calibration mode, or X-Y position mode, shows the realtime position of the surface ships track via GPS, LORAN, or Mini-Ranger III and calculated transponder locations based upon the slant ranges calculated from data received by the NS-011. Realtime calculations and display of transponder positions are done on a very limited data set, and as such, the least squares fit algorithms used by the program will not provide transponder position accuracies as good as postprocessing of a large data set.

FIXSUMMA.EXE

The data taken during the execution of AUSSCALB.EXE may have as many as four range returns per transponder for each interrogation of the network. Only one of the possible four returns represents the true slant range path between the surface ship and the respective transponder. FIXSUMMA.EXE was developed as an editing tool to read NS011-XX.YYY data files and plot range-versus-time information graphically on

the computer screen. Figure 32 shows how these raw data files are displayed. From the sample figure, it is clearly evident that more than one return was received by the NS-011 for the same net interrogation. Slant range plots for each tranponder must be analyzed to determine correct and incorrect returns received by the NS-011. Points that represent false slant range returns should be eliminated from data files. All remaining points should lie along a smooth path as shown in figure 32. These points represent the true slant range returns for a selected transponder as the ship moves around the network collecting data. Points that jump away from the smooth path represent what are commonly called "flyers." They are caused by multipath signals reflecting off the ocean bottom or surface. Broadband noise may also cause the NS-011 to record incorrect transponder slant ranges.
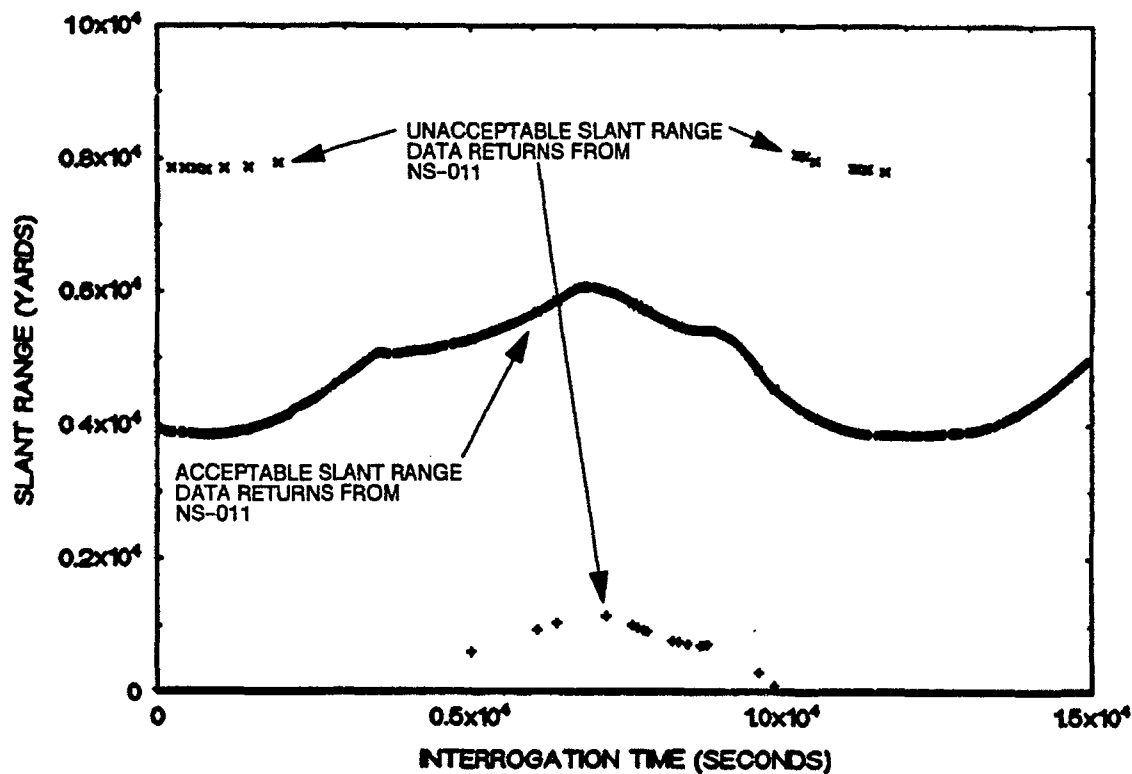
Figure 32. Recorded NS-011 slant range data between surface ship and selected transponder.

FIXSUMMA.EXE allows an operator to quickly determine false range returns and eliminate them from the data files. The elimination process is done using a digitizing pad attached to the computer's COM1 serial port. The program has a rubberband mode controlled by the digitizing pad pen. False data points are eliminated by establishing a rubberband line above or below the bad data. Once the line is established, depressing the "SHIFT A" or "SHIFT B" keys on the keyboard will eliminate *all* data points above or below the line, respectively. Edited data are written to files upon

exiting the program. Edited data files are given names such as BOUY01.XXX. Figure 33 shows the result of editing the data shown in figure 32. Examples of partial NS011—XX.YYY and BOUYXX.YYY data files are given in appendix B.

SHUFFLE.EXE

SHUFFLE.EXE makes further corrections to the raw data collected from AUSSCALB.EXE. The filtered slant range values of the BUOYyy.xxx files are converted back to round-trip times by multiplying slant range by two and dividing by sound speed. Round-trip times are then modified to account for transponder turnaround times inherent in all underwater transponders. Transponder turnaround times are stored in the ASCII data file TURNARND. The turnaround times are read by SHUFFLE.EXE and are then subtracted from the respective transponder round-trip times derived from the BUOYyy.xx files. A sample TURNARND file showing the data file format structure is shown in appendix B. The sample file shows the turnaround times for an eight-transponder network.
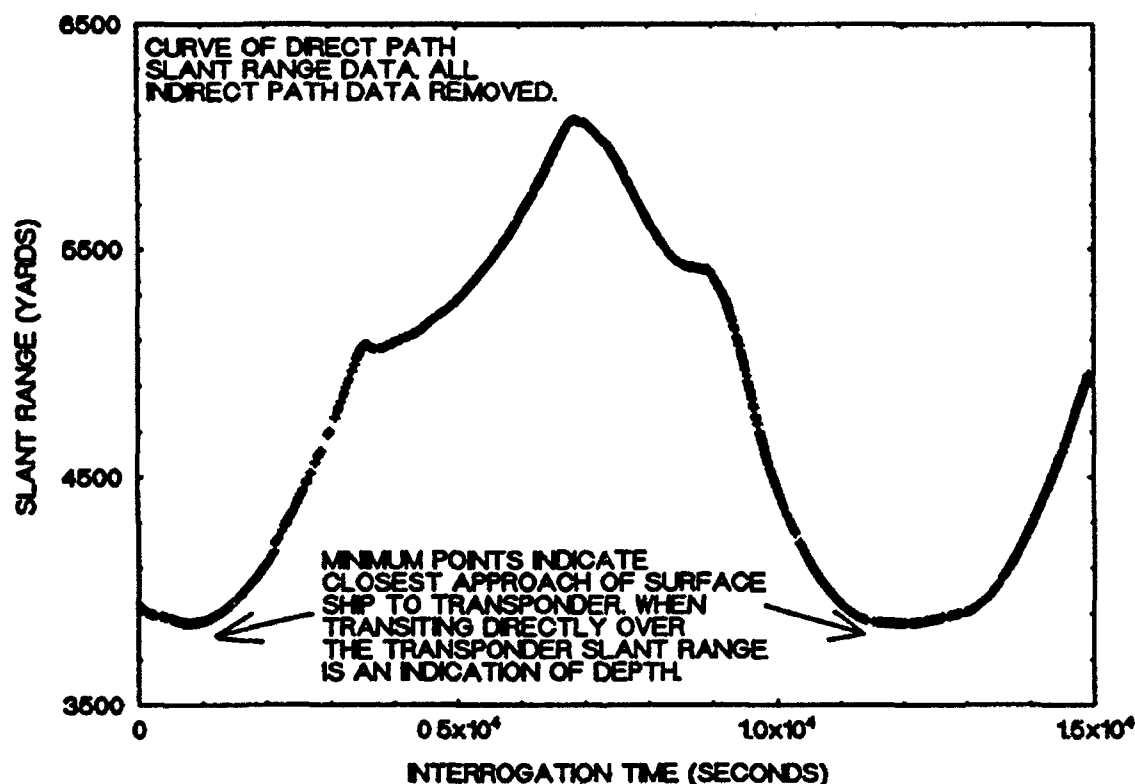
Figure 33. Edited data of figure 32 showing only the direct path slant ranges between the surface ship and transponder. All indirect slant range data removed using FIXSUMMA.EXE program.

56

If not accounted for, transponder turnaround times introduce errors in calibrated transponder positions because respective slant ranges appear greater than they actually are. For example, a 3-msec turnaround time when multiplied by a sound speed of 4890 feet per second adds approximately 5 yards to round-trip slant range values.

As mentioned above (see RAYCOR.BAT), a general discussion of the effects water temperature has on sound velocity was explained. SHUFFLE.EXE uses the resulting third-degree polynomial cofficients generated by RACOR.BAT to make additional corrections to round-trip times computed from the BUOYyy.xxx files. SHUFFLE.EXE does not require ray correction data to operate; however, the resulting data stored in RANGES.XXX could be in error by several yards depending upon the severity of ray bending.

The ASCII file MAXRANGE specifies the maximum acceptable range for each transponder that can be used in the calibration process. SHUFFLE.EXE uses this information to provide a basic slant range filter to eliminate unacceptable data that remain in the BUOYyy.XXX files. For every slant range SHUFFLE.EXE reads, a calculation is performed on the data to determine if the value is less than the values stored in MAXRANGE for respective transponders. If it is less, the value is stored in RANGES.XXX. If the data value is greater, it is discarded and no further calculations are performed. A typical example of a MAXRANGE data file showing a maximum acceptable value of 5000 yards for each of eight network transponders is shown in appendix B.

The SHUFFLE.EXE program outputs data to files named RANGES.xxx. The data consists of time marks and corrected ranges from each transponder BUOYyy.xxx file. The first column represents time marks recorded during the data collection process. Time is recorded as seconds of elasped time past midnight local time. The following columns represent range values in yards for the direct path between each transponder and the surface ship. A few lines of a sample RANGES.xxx data file are shown in appendix B. The file RANGES.xxx is the primary data file used by subsequent calibration programs for determining relative transponder positions.

ITERATE.BAT

Up to this point in the discussion of the transponder network calibration process, collected data have been processed in preparation for the algorithms that ultimately determine the relative positions of the transponders with respect to one another. ITERATE.BAT is an executable DOS batch program that controls the execution of LBLNAV.EXE and CALIBRAT.EXE programs. This can be seen from the program lines shown below. The first program line will execute LBLNAV.EXE using parameters stored in the ASCII data file PARAMS1. After LBLNAV.EXE terminates, ITERATE.BAT executes CALIBRAT.EXE using parameters stored in ASCII data file PARMS2. When CALIBRAT.EXE terminates, execution of LBLNAV.EXE is once again performed. This process continues until that last line of the batch file is executed. If ITERATE.BAT terminates before the locations of the network transponders

stablize (i.e., no apparent movement of transponder positions through one cycle of LBLNAV.EXE and CALIBRAT.EXE), then ITERATE.BAT should be rerun until stabilization occurs.

ITERATE.BAT

```
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
lblnav<parms1
calibrat<parms2
```

LBLNAV.EXE and CALIBRAT.EXE

LBLNAV.EXE and CALIBRAT.EXE are the primary executable programs for performing relative transponder network calibration calculations. The main computations involve least squares fit algorithms using transponder slant range data. Figure 31 shows their interrelationship with other programs and data files. As mentioned previously, program execution control for LBLNAV.EXE and CALIBRAT.EXE is determined by the batch program ITERATE.BAT. LBLNAV.EXE and CALIBRAT.EXE collectively determine the relative positions of deployed transponders given the information in RANGES.xxx, XPONPOS, and FIRSTFIX data files. The file RANGES.xxx was discussed earlier. The data stored in XPONPOS initally contain information about the surface drop points (in Lambert state plane coordinates) of the transponders during the deployment phase of the network. FIRSTFIX is a single Lambert coordinate (generally the center position of the transponder network) from which LBLNAV.EXE gets its first initial position guess. This data point will be discussed in more detail later.

Data files XPONPOS and FIRSTFIX must be present before executing ITER-ATE.BAT and the calibration process. Appendix B shows sample ASCII XPONPOS and FIRSTFIX data files for a five-transponder network. For proper program execution, the XPONPOS shown in appendix B must be converted from an ASCII file to a binary file using the program ASCTOBIN.EXE. FIRSTFIX does not require conversion to binary format, and is used by LBLNAV.EXE as listed in appendix B.

The first step in the calibration process is performed by LBLNAV.EXE. The program opens the binary data file RANGES.xxx and reads the first line of data collected from a single interrogation of the transponder network. The data files XPONPOS and FIRSTFIX are opened and the initial transponder drop point positions and a first fix ship position coordinates is read by the program. Computations to determine range to each transponder are performed using the FIRSTFIX coordinates of the ships position and the transponder positions recorded in XPONPOS. Calculated ranges to each transponder are then compared to actual measured ranges for each interrogation. For a specific ship position coordinates, a numerical error is computed using the sum of the squares of the differences between calculated and measured ranges. The ship's position is changed slightly from the initial coordinates and a new set of ranges is calculated and compared to the measured ranges. The wiggling of the ship's position continues until the error between calculated and measured ranges converges to a minimum value. The interrogation time, the ship's position, and an rms error for the interrogation is then stored in the data file SOLUTES.xxx. The range errors and interrogation time for each transponder are stored in data file ERRORS.xxx. This process repeats itself for each line of data in RANGES.xxx. When LBLNAV.EXE terminates, control is passed back to ITERATE.BAT for the execution of CALIBRAT.EXE.

The second step of the process is performed by CALIBRAT.EXE. The purpose of this program is to modify the coordinates of the transponder positions stored in XPON-POS using the ranges stored in RANGES.xxx, the ship's position recorded in the SOL-UTES.xxx data files, and the initial transponder drop point positions stored in XPON-POS. The position for a single transponder relative to the position of a surface ship can be computed using ranges from three or more surface ship fixes and the positions of the ship fixes. The least squares fit algorithm used by CALIBRAT.EXE uses the transponder's coordinates and then computes the range between the ship and the transponder for each ship position. The calculated range and the actual measured range for each interrogation are compared, and an error equal to the sum of the squares of the differences between the two is computed. This sum is taken over all ship fixes. The transponder position is now changed slightly and a new set of ranges is computed and compared to measured ranges. The wiggling of the transponder position is continued until the error between calculated and measured ranges converges to a minimum value. This process is conducted for each transponder deployed in the network. The output of CALIBRAT.EXE is a modified XPONPOS data file with the new transponder coordinates. When CALIBRAT.EXE terminates, control is passed back to ITERATE.BAT for execution of LBLNAV.EXE.

The iterative process that exists between LBLNAV.EXE and CALIBRAT.EXE continues back and forth, first fixing the positions of the tranponders and computing the ship's track, and then fixing the ship's track and computing new transponder positions. Each time through the cycle, the numerical values stored in SOLUTS.xxx and XPONPOS are updated with new figures. As the iterative process continues, the error of each algorithm should decrease, and a point should be reached where movement of the transponder positions and the ship's track is negligible. A relative calibration of the transponder network is achieved at this point.

GEODECAL.EXE

The final step in the network calibration process is to modify the relative transponder coordinates stored in XPONPOS so that each transponder's position is assigned a geodetic location. The program that does this task is GEODECAL.EXE. Its relationship to the other network calibration processes is shown in figure 31. GEODECAL.EXE inputs consist of relative long baseline ship positions stored in SOLUTES.xxx, the relative calibration transponder positions stored in XPONPOS, and geodetic ship positions stored in SSHIP.xxx. The geodetic ship position information recorded during the data collection operation could be from Mini-Ranger III, GPS, DGPS, or LORAN-C navigation receivers.

Relative transponder positions require translation, rotation, and scaling to convert coordinates to absolute geodetic locations. The ship's track by Mini-Ranger III, GPS, DGPS, or LORAN-C is the baseline from which this conversion will be computed. A comparison is made using least squares fit algorithms between the geodetic ship positions and the computed LBL positions stored in SOLUTES.xxx. Linear interpolation is required on position data stored in SSHIP.xxx because the marked fix times do not map one-to-one with data in SOLUTES.xxx. The GEODECAL.EXE least squares fit algorithm determines how much x-translation, y-translation, rotation, and scale factor is required for the best fit of LBL ship track data with geodetic ship track data. Once these values are determined, they are applied to the relative transponder positions stored in XPONPOS. The relative transponder positions of XPONPOS are modified by GEODECAL.EXE to reflect the computed geodetic positions. These positions represent Lambert state plane coordinates and are used by AINS software for LBL tracking of a surface ship or the AUSS vehicle.

TRANSPONDER NETWORK CALIBRATION RESULTS

Physically determining the geodetic position of an underwater transponder to verify calibration results is impractical and in many cases may be impossible. Verifying the geodetic calibration results for an installed transponder network is best left to the analysis of data resulting from the calibration process.

During the execution of the calibration routines, data are generated to analyze calibration accuracy indirectly. Residual range errors, which are defined as calculated

ship-to-transponder slant ranges minus measured slant ranges, are determined for each transponder and network interrogation. When range arcs from three or more transponders are used to determine position, an area of uncertainty is established because the arcs will not intersect at a single point. Residual error is an indication of the size of the area of uncertainty.

The data file ERRORS.xxx is created during the calibration process by LBLNAV.EXE. This file contains final residual error values for each transponder and network interrogation. Depending upon the interrogation rate set during the data collection process, the ERRORS.xxx files may contain several hundred entries for each transponder. Determining the rms value of residual range errors for each transponder yields a statistically significant parameter. Figure 34 is a plot of the residual range errors for a typical transponder calculated by LBLNAV.EXE. The rms value of the residual errors for this transponder was calculated to be 0.8 yard.

The comparison of the LBL ship's track and the ship's track using an accurate tracking system such as Mini-Ranger III is another indirect indicator of network calibration accuracy. As mentioned earlier, a well-calibrated Mini-Ranger III system can reliably track a surface vessel to within 3 to 6 yards. Figures 35 and 36 are overlays of a ship's LBL and Mini-Ranger III track, and ship's LBL and GPS track, respectively, during transponder network calibration operations. Figure 35 shows the results of rotating and translating the ship's LBL track to align it with the Mini-Ranger track. This graphically shows, using independent systems, that the transponder network calibration is valid. Figure 36 shows the results of a network calibration using the ship's relative LBL track and the GPS track before translation and rotation.

NAVIGATION AND TRACKING MISSION PLANNING

The key to any successful operation involves sufficient planning to carry out the mission in an efficient manner. AUSS dive plans are developed and reviewed before departure on an operation, defining dive objectives. From these dive plans, navigation and tracking issues are addressed and the appropriate hardware and software is configured and checked for proper operation. The integrated navigation systems, Seatrac and AINS, are configured for specific mission scenarios as defined in the dive plan. Matters such as dive location, search area, tracking methods, and vehicle search patterns are established before departing port. Contingency plans are established to account for any unforeseen deviations in the main dive plan.
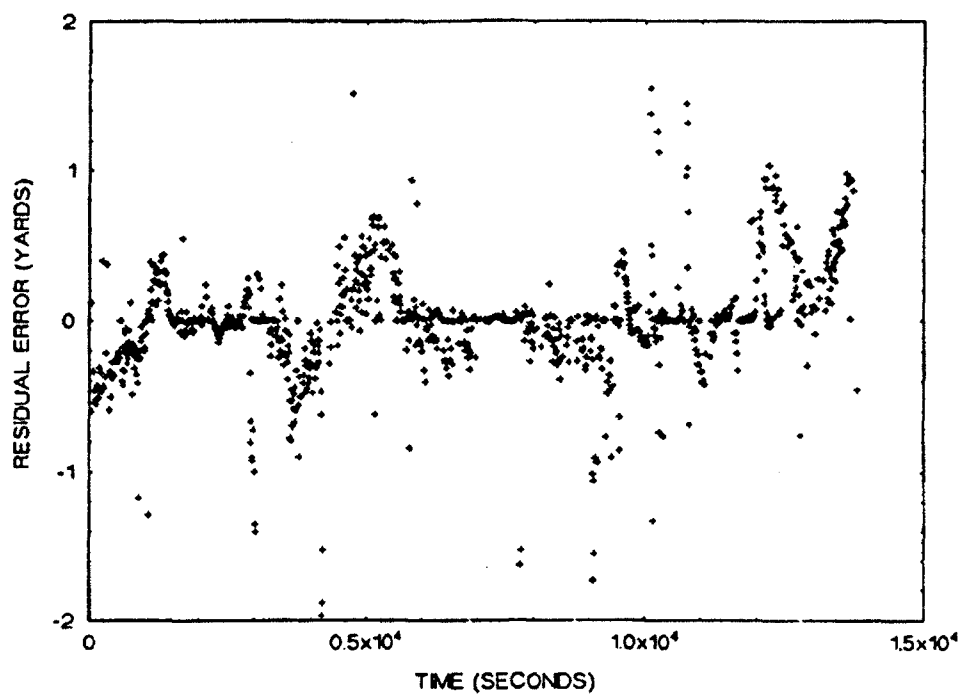
Figure 34. Typical residual range errors for a single transponder of a calibrated transponder network.
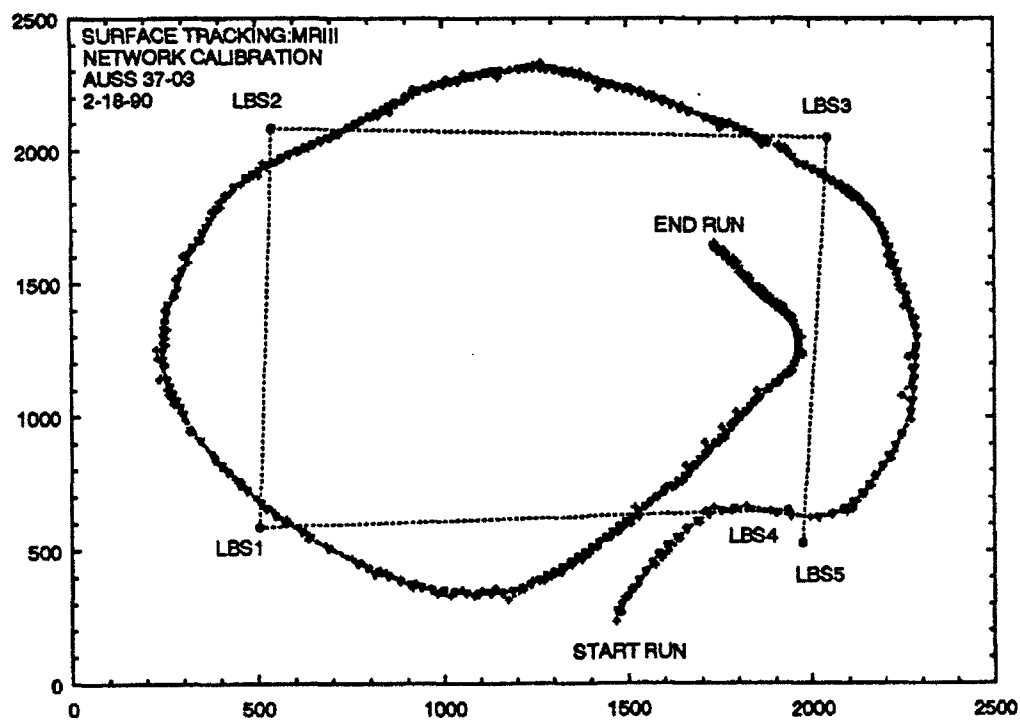
Figure 35. Overlay of ship's LBL and Mini-Ranger III track.
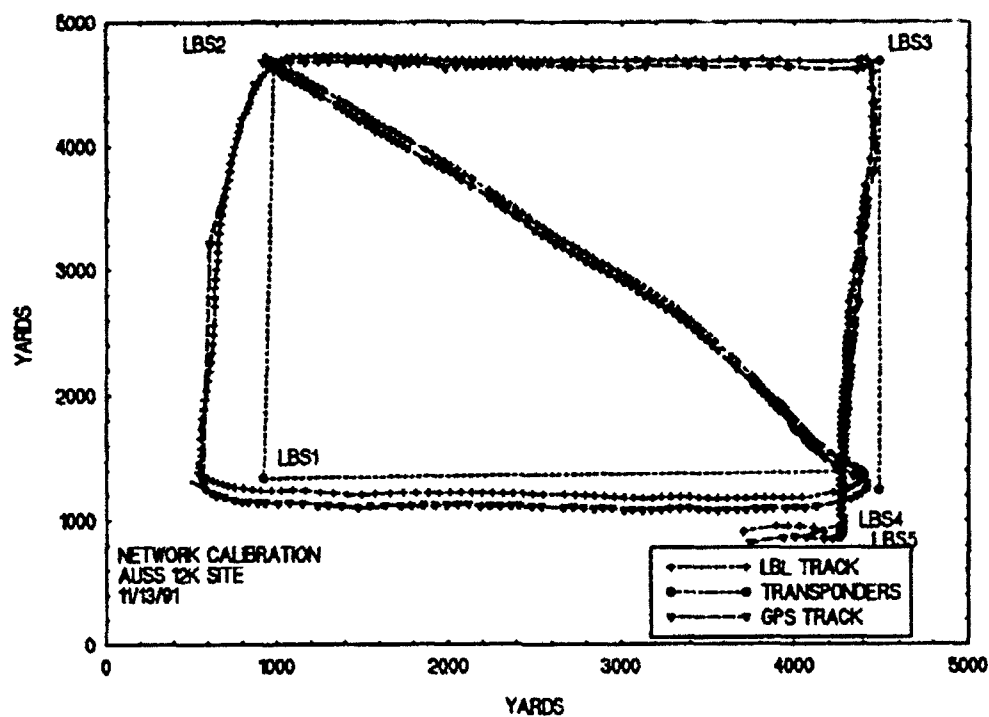
Figure 36. Overlay of LBL and GPS track.

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APPENDIX A

SEATRAC MENUING

This appendix details the main pop-up menuing system used in the Seatrac Integrated Navigation System. The menus are included in this report to give the reader insight concerning the program's capability and useability. A brief description of the menu function and setup is also provided. Further information concerning Seatrac software installation and user functions can be found in the Seatrac II Integrated Navigation and Data Management System (Version 2.0) manual, dated March 1989, by Seaquest Associates.

```
┌─────────────────────┐
│   Try Another?      │
├─────────────────────┤
│ │No                 │
│ │Yes                │
└─────────────────────┘

┌─────────────────────────────────────────┐
│   Enter An Initial Position Estimate     │
├─────────────────────────────────────────┤
│   Latitude      00° 00' 00.00" N         │
│   Longitude    000° 00' 00.00" E         │
│                                          │
│   Northings       -12574913              │
│   Eastings         42817181              │
└─────────────────────────────────────────┘
```

1. THE INITIAL POSITION MENU IS THE FIRST DATA ENTRY MENU THAT APPEARS
UPON EXECUTING THE SEATRAC NAVIGATION SOFTWARE.

2. AN INITIAL POSITION ESTIMATE MUST BE ENTERED IN THE LATITUDE/LONGITUDE
OR NORTHINGS/EASTING FIELDS FOR PROPER OPERATION. PRESS ESC FOR NEXT MENU.

3. SELECT NO FROM TRY ANOTHER MENU IF DATA IS OK. RETURN FOR NEXT MENU.

```
┌─────────────────────────┐        SEATRACå    ┌─────────────────────────┐
│                         │        àààààààà    │                         │
│ Position                │                    │ Position                │
│                         │       ┌────────┐   │                         │
│                         │       │MISSION │   │                         │
│ COG              true   │       │OP_AREA │   │ COG              true   │
│ HDG                     │       │SETUP   │   │ HDG                     │
│                         │       │DEVICES │   │                         │
│ SOG              kts    │       │NAVAIDS │   │ SOG              kts    │
│ SPD                     │       │RATES   │   │ SPD                     │
│                         │       │MISC    │   │                         │
│ Vector To               │       │EXIT    │   │ Vector To               │
│ Range                   │       └────────┘   │ Range                   │
│ Bearing                 │                    │ Bearing                 │
│ TTG                     │                    │ TTG                     │
│                         │                    │                         │
│ Offset                  │                    │ Offset                  │
│ Closing Rate            │                    │ Closing Rate            │
│ Made Good               │                    │ Made Good               │
│                         │                    │                         │
│                         │                    │ Altitude                │
│ Bottom Depth            │                    │ Depth                   │
└─────────────────────────┘        14:29:51    └─────────────────────────┘
```

1. MAIN SEATRAC NAVIGATION PORTAL. THE LEFT AREA OF THIS PORTAL IS FOR
SURFACE NAVIGATION DATA. THE RIGHT AREA IS FOR SUBMERSIBLE TRACKING DATA.
THE CENTER MENU IS FOR SELECTING NAVIGATION/TRACKING SOFTWARE OPERATING
PARAMETERS.

2. DISPLAYED NAVIGATION/TRACKING DATA INCLUDES: POSITION (LATITUDE/LONGITUDE,
NORTHINGS/EASTINGS, X,Y) OF SURFACE SHIP/SUBMERSIBLE. COURSE OVER GROUND (COG)
DEGREES TRUE, SPEED OVER GROUND (SOG) KNOTS, VECTOR TO: RANGE, BEARING AND
TIME-TO-GO (TTG) FROM CURRENT POSITION TO SELECTED GEODETIC POSITION. OFFSET,
CLOSING RATE, AND MAKING GOOD FROM PRESENT SHIP/SUBMERSIBLE POSITION TO
SELECTED LOCATION IN POSITION TABLE. ALTITUDE AND DEPTH OF SUBMERSIBLE.

```
┌──────────┐        ┌──────────────┐        ┌───────────────┐
│MISSION   │ <<     │Load          │ <<     │ Mission Files │
│OP_AREA   │        │Save          │        │               │
│SETUP     │        │Print         │        │ 12KSPOT.MIS   │
│DEVICES   │        │              │        │ 2KSPOT.MIS    │
│NAVAIDS   │        └──────────────┘        │ 37-03.MIS     │
│RATES     │                                │ 37-03A.MIS    │
│MISC      │                                │ 37-03B.MIS    │
│EXIT      │                                │ 37-03C.MIS    │
│          │                                │ 37-03D.MIS    │
└──────────┘                                │ ALT12K.MIS    │
                                            └───────────────┘
```

```
┌────────────────────────────┐
│ Mission File Name:          │   << THIS MENU IS FOR SAVING A MISSION FILE
└────────────────────────────┘
```
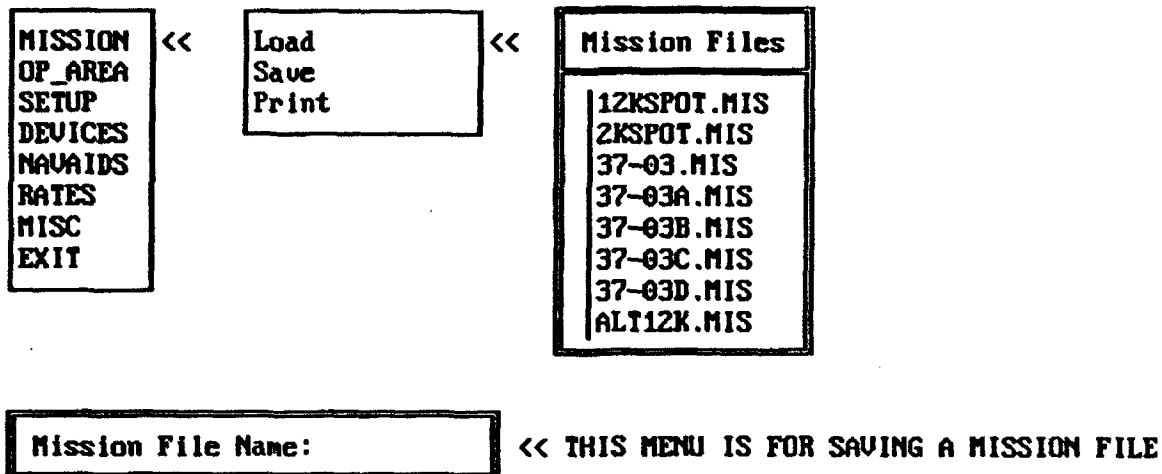
1. SELECTING MISSION FROM THE CENTER MENU OF THE MAIN NAVIGATION SCREEN
WILL DISPLAY A POP-UP MENU FOR LOADING, SAVING OR PRINTING MISSION FILES.
MISSION FILES CONTAIN DATA ON BLOCK TABLE, POSITION TABLE, WAYPOINT TABLE,
AND TRACK TABLE ENTRIES. PLOTTER AND DISPLAY SETTINGS, DATA LOGGING RATES,
AND MISCELLANEOUS NAVIGATION SET-UP PARAMETERS ARE STORED IN MISSION FILES.

A-4

```
┌──────────────┐   ┌────────────────┐
│ MISSION      │   │ Positions │ << │
│ OP_AREA │ << │   │ Waypoints      │
│ SETUP        │   │ Blocks         │
│ DEVICES      │   │ Tracks         │
│ NAVAIDS      │   │ Contacts       │
│ RATES        │   └────────────────┘
│ MISC         │
│ EXIT         │
└──────────────┘
```

P o s i t i o n   T a b l e

#	Description	Northings		Eastings		Symbol	Color
4	LBS4	-2035	N	2266	E	X	GRAY
5	BOUY 5	-120568	N	89085	E	CIRC	GRAY
6	BOUY 6	-120465	N	89852	E	CIRC	GRAY
7	BOUY 7	-115406	N	88475	E	CIRC	GRAY
8	BOUY 8	-115809	N	89328	E	CIRC	GRAY
9	BOUY 9	-112775	N	88126	E	CIRC	GRAY
10	BOUY 10	-112671	N	88808	E	CIRC	GRAY
11	BOUY 11	-109738	N	87777	E	CIRC	GRAY
12	BOUY 12	-109635	N	88544	E	CIRC	GRAY
14	BOUY 14	-104776	N	87934	E	CIRC	GRAY

1. THE OP_AREA SELECTION FROM THE MAIN NAVIGATION SCREEN ENABLES THE
OPERATOR TO ESTABLISH POSITION POINTS, WAYPOINTS, BLOCKS, TRACK LINES,
AND CONTACTS ON THE INS HIGH RESOLUTION GRAPHICS SCREEN. POSITIONS ARE
DISPLAYED ON THE GRAPHICS SCREEN USING SYMBOLS AND ASSIGNED NUMBERS.

2. POSITION TABLE ENTRIES ARE ENTERED/DELETED USING THE KEYBOARD INSERT/
DELETE KEYS. THE F10 FUNCTION KEY CAN BE USED TO ENTER THE LATEST
POSITION OF THE SURFACE VESSEL AND SUBMERSIBLE INTO THE POSITION TABLE.

```
┌──────────┐          ┌───────────┐
│MISSION   │          │Positions  │
│OP_AREA   │ <<       │Waypoints  │ <<
│SETUP     │          │Blocks     │
│DEVICES   │          │Tracks     │
│NAVAIDS   │          │Contacts   │
│RATES     │          └───────────┘
│MISC      │
│EXIT      │
└──────────┘
```

W a y p o i n t   T a b l e

#	Description	Northings	Eastings

1. THE WAYPOINT TABLE IS USED TO ESTABLISH A SERIES OF STARTING AND ENDING POINT LEGS FOR WAYPOINT NAVIGATION. WAYPOINTS ARE DISPLAYED ON THE HIGH RESOLUTION GRAPHICS SCREEN AND ARE USED AS AN AID TO NAVIGATION FOR GETTING THE SURFACE VESSEL FROM A STARTING POINT TO AN ENDING POINT.
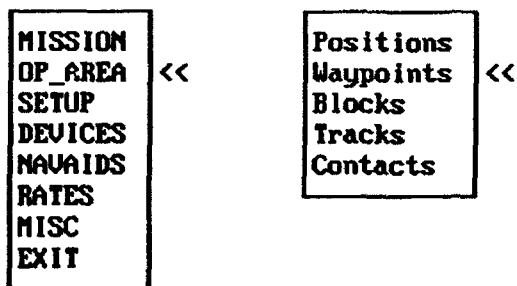
2. ENTRIES ARE INPUT MANUALLY BY PRESSING THE KEYBOARD INSERT KEY. THE DELETE KEY IS USED TO REMOVE AN ENTRY FOR THE WAYPOINT TABLE.

```
┌──────────┐      ┌──────────────┐
│ MISSION  │      │ Positions    │
│ OP_AREA  │ <<   │ Waypoints    │
│ SETUP    │      │ Blocks       │ <<
│ DEVICES  │      │ Tracks       │
│ NAVAIDS  │      │ Contacts     │
│ RATES    │      └──────────────┘
│ MISC     │
│ EXIT     │
└──────────┘
```

B l o c k   T a b l e

#	Center North	Center East	Length	Width	Orientation
1	0 N	0 E	2000	2000	0.0

1. THE BLOCK TABLE IS USED TO DEFINE RECTANGULAR BLOCKS FOR DISPLAY
ON A HIGH RESOLUTION GRAPHICS SCREEN. ENTRIES/DELETIONS ARE ENTERED
USING THE INSERT/DELETE KEYBOEARD KEYS RESPECTIVELY. BLOCKS ARE DEFINED
BY A CENTER POINT IN NORTHINGS/EASTINGS, X/Y, OR LATITUDE/LONGITUDE AND
LENGTH AND WIDTH. BLOCKS CAN BE ROTATED USING THE ORIENTATION FIELD.
POSITIVE DEGREES ROTATE THE BLOCK IN A COUNTER CLOCKWISE DIRECTION.

2. BLOCKS ARE USEFUL FOR AIDING NAVIGATION AND FOR DEFINING THE
PERIMETER OF AN OPERATIONAL AREA.

```
┌──────────┐         ┌──────────────┐
│MISSION   │         │Positions     │
│OP_AREA   │ <<      │Waypoints     │
│SETUP     │         │Blocks        │
│DEVICES   │         │Tracks        │ <<
│NAVAIDS   │         │Contacts      │
│RATES     │         └──────────────┘
│MISC      │
│EXIT      │
└──────────┘
```
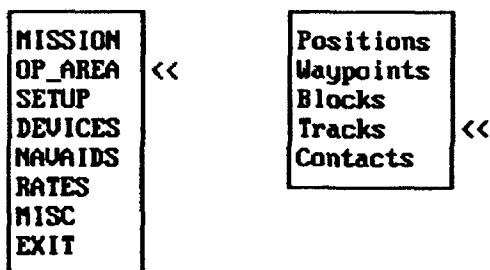
T r a c k   T a b l e

#	Start North		Start East		End North		End East	
1	-107020	N	81549	E	-114813	N	83188	E
2	-114813	N	83188	E	-115925	N	83873	E
3	-115925	N	83873	E	-115923	N	84640	E
4	-115923	N	84640	E	-113489	N	86083	E
5	-113489	N	86083	E	-109947	N	85392	E
6	-109947	N	85392	E	-108019	N	87091	E
7	-108019	N	87091	E	-107404	N	85470	E
8	-107415	N	85470	E	-104176	N	85121	E
9	-104176	N	85121	E	-101845	N	85967	E
10	-101845	N	85967	E	-99213	N	85790	E

1. THE TRACK TABLE IS USED TO DEFINE TRACK LINES THAT ARE DISPLAYED
ON A HIGH RESOLUTION GRAPHICS DISPLAY. TRACK LINES CAN BE USED AS AN
AID TO NAVIGATION BY PRESENTING VISUAL REFERENCE MARKINGS FOR SHIP
STEERAGE. ENTRIES/DELETIONS ARE ENTERED USING THE KEYBOARD INSERT/DELETE
KEYS RESPECTIVELY. STARTING AND ENDING COORDINATES CAN BE ENTERED IN
NORTHINGS/EASTINGS, X/Y, OR LATITUDE/LONGITUDE.

```
┌──────────┐      ┌──────────┐
│MISSION   │      │Graphics  │ <<
│OP_AREA   │      │Plotter   │
│SETUP     │ <<   └──────────┘
│DEVICES   │
│NAVAIDS   │
│RATES     │
│MISC      │
│EXIT      │
└──────────┘
```

```
┌───────────────────────────────────────────────────────────────┐
│                  Graphics Screen Parameters                     │
├───────────────────────────────┬─────────────────────────────────┤
│                               │                                 │
│     Center On  VESSEL         │                  COLORS          │
│                               │        Vessel   BR WHITE         │
│        Scale  1:50000         │                                 │
│                               │        Remote   BR MAGENTA       │
│     Rotation     0            │                                 │
│                               │        Blocks   GRAY             │
│       Update  SHIFT           │                                 │
│                               │        Tracks   BLUE             │
│  Vehicle History  VESSEL      │                                 │
│       Positions   50          │      Waypoints  GREEN            │
│                               │                                 │
│  Depth History  DEPTH         │        Border   GRAY             │
│  Critical Depth     0         │                                 │
│                               │                                 │
└───────────────────────────────┴─────────────────────────────────┘
```

1. THE GRAPHICS SCREEN PARAMETER MENU IS USED TO CONFIGURE THE WAY INWHICH NAVIGATION DATA IS DISPLAYED ON THE HIGH RESOLUTION GRAPHICS DISPLAY. CONFIGURATION OF PARAMETERS IS ACCOMPLISHED BY HIGHLIGHTING THE DESIRED FIELD USING THE CURSOR UP/DOWN AND LEFT/RIGHT KEYS AND PRESSING ENTER.

THE FOLLOWING MENUS ARE AVAILABLE FOR CONFIGURING GRAPHIC SCREEN PARAMETERS. SYSTEM OPERATION DOES NOT DEPEND ON SPECIFIC PARAMETER SELECTIONS FROM THESE MENUS.

CENTER ON POP-UP MENU	SCALE POP-UP MENU	UPDATE POP-UP MENU	VEHICLE HISTORY POP-UP MENU	DEPTH HISTORY POP-UP MENU	SCREEN COLOR OPTIONS MENU
VESSEL	1:5	OFF	OFF	OFF	BLUE
REMOTE	1:10	SHIFT	VESSEL	DEPTH	GREEN
POSITION	1:20	SCALE	REMOTE		CYAN
BLOCK	1:50	BOTH	BOTH		RED
AUTO	1:100				MAGENTA
	1:200				YELLOW
	1:500				WHITE
	1:1000				GRAY
	1:2000				Bl. BLUE
	1:5000				BR GREEN
	1:10000				BR CYAN
	1:20000				BR RED
	1:50000				BR MAGENTA
	1:100000				BR YELLOW
					BR WHITE

A-9

```
┌─────────┐         ┌──────────┐
│MISSION  │         │Graphics  │
│OP_AREA  │         │Plotter   │ <<
│SETUP    │ <<      └──────────┘
│DEVICES  │
│NAVAIDS  │
│RATES    │
│MISC     │
│EXIT     │
└─────────┘
```
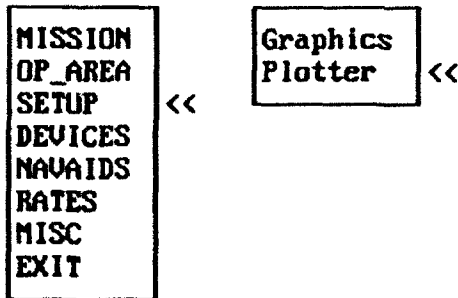
```
┌─────────┐                    ┌────────┐
│POSITION │ CENTER ON          │LARGE   │ FIX MARK
│BLOCK    │ POP-UP             │SMALL   │ POP-UP
│WAYPOINT │ MENU               └────────┘ MENU
└─────────┘
```

┌───┐
│   Plotter Parameters   │
├─────────────────────────────────┬─────────────────────────────────┤
│   Label test   │   VESSEL   REMOTE │
│   │   │
│ Center On POSITION # 1   │ Fix Mark LARGE   Fix Mark LARGE│
│   │   │
│   Scale 1:200   │   Connect OFF   Connect OFF │
│   │   │
│   Legend OFF   │   Move Arm OFF   Move Arm OFF │
│   Blocks OFF   │   │
│ Positions OFF   │   Annotate OFF   Annotate OFF │
│ Waypoints OFF   │   │
│ Contacts OFF   │   Frequency 0   Frequency 0 │
│   Tracks   │   │
└─────────────────────────────────┴─────────────────────────────────┘

1. CONFIGURATION OF THE PRESENTATION OF DATA ON THE PEN PLOTTER IS
ACCOMPLISHED USING THE PLOTTER PARAMETERS MENU. PLOT CENTERING AND
FIX MARK OPTIONS ARE SHOWN IN THE ABOVE POP-UP MENUES. SCALE OPTIONS
ARE THE SAME AS SHOWN FOR GRAPHIC PARAMETERS. THE REMAINING FIELDS OF
THIS MENU ARE CONFIGURED BY HIGHLIGHTING EACH FIELD AND SELECTING ON/OFF
FROM THE POP-UP MENU. FOR EXAMPLE: IF IT IS DESIRED TO CONNECT THE
POSITION POINTS RECORDED BY THE PLOTTER WITH STRAIGHT LINES THE "CONNECT"
FIELD WOULD BE TURNED ON FOR THE VESSEL AND/OR THE REMOTE SUBMERSIBLE.

```
┌──────────┐        ┌──────────┐
│ MISSION  │        │ Vessel   │ <<
│ OP_AREA  │        │ ROV      │
│ SETUP    │        └──────────┘
│ DEVICES  │ <<
│ NAVAIDS  │
│ RATES    │
│ MISC     │
│ EXIT     │
└──────────┘
```
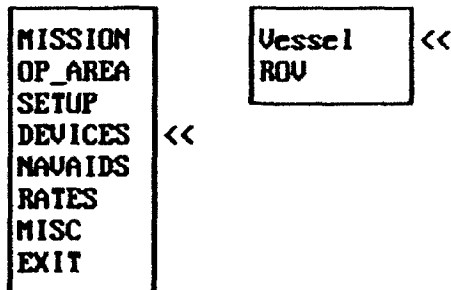
Trimble 10X GPS/LoranC	MiniRanger III	Honeywell RS906 LBS
Posit -12574913 N	Posit	Posit
DR 42817181 E		
Elapsed Time 02:43	Elapsed Time	Elapsed Time
Priority 1	Priority OFF	Priority OFF
Sample Rate 5	Sample Rate 5	Sample Rate 1
Window 0	Window 0	Window 0
Other RECEIVERS	Other RECEIVERS	Other RECEIVERS

1. THE VESSEL DEVICES MENU DISPLAYS CURRENT POSITION INFORMATION CALCULATED
FROM RAW DATA PROVIDED BY ACTIVE SURFACE NAVIGATION HARDWARE. HARDWARE
SENSORS ARE ACTIVATED BY HIGHLIGHTING THE PRIORITY FIELD AND ASSIGNING A
NUMERICAL VALUE TO IT FROM 1 TO 3. ONE (1) IS THE HIGHEST SENSOR PRIORITY.
IF A SENSOR WITH A HIGHER PRIORITY FAILS TO PROVIDE GOOD DATA THE SOFTWARE
AUTOMATICALLY SWITCHES TO THE HIGHEST PRIORITY SENSOR PROVIDING GOOD DATA.

2. THE RATE AT WHICH THE SEATRAC WILL LOOK FOR DATA AT ITS INPUT PORTS IS
DETERMINED BY THE SETTING OF THE "SAMPLE RATE" FIELD. IN THE ABOVE EXAMPLE
DATA FROM THE TRIMBLE 10X GPS/LORAN-C RECEIVER IS ACCEPTED BY THE SOFTWARE
EVERY 5 SECONDS. THE ELAPSED TIME COUNTER DISPLAYS THE TIME SINCE THE LAST
GOOD FIX WAS RECEIVED.

3. RAW INPUT DATA FROM EACH ACTIVE SENSOR CAN BE VIEWED BY SELECTING THE
"OTHER FIELD" IN EACH PORTAL.

```
┌─────────┐          ┌──────────┐
│MISSION  │          │Vessel    │
│OP_AREA  │          │ROV       │ <<
│SETUP    │          └──────────┘
│DEVICES  │ <<
│NAVAIDS  │
│RATES    │
│MISC     │
│EXIT     │
└─────────┘
```
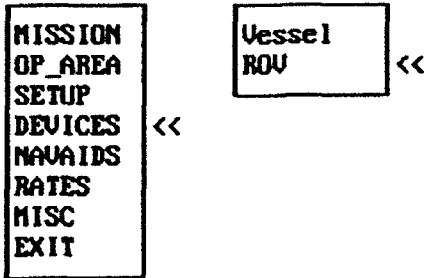
Honeywell RS90X 2B		Honeywell RS906 LBS		Manual Layback	
Posit		Posit		Posit	
Elapsed Time		Elapsed Time		Elapsed Time	
Priority	OFF	Priority	OFF	Priority	OFF
Sample Rate	5	Sample Rate	1	Sample Rate	1
Window	0	Window	0	Window	0
Other	RECEIVERS	Other	RECEIVERS	Other	RECEIVERS

1. THE ROV DEVICES MENU DISPLAYS TRACKING INFORMATION CALCULATED FROM RAW
DATA PROVIDED BY ACTIVE UNDERWATER TRACKING HARDWARE SUCH AS THE HONEYWELL
RS906 LONG AND ULTRA-SHORT BASELINE TRACKING SYSTEMS. THIS MENU OPERATES
EXACTLY LIKE THE VESSEL DEVICES MENU PREVIOUSLY DESCRIBED.

```
┌─────────┐   ┌──────────────────────┐
│MISSION  │   │Making Good           │
│OP_AREA  │   │Vectoring             │  <<
│SETUP    │   │Waypoint Navigation   │
│DEVICES  │   └──────────────────────┘
│NAVAIDS  │ <<
│RATES    │   ┌──────────────────────────────────────┐
│MISC     │   │                                      │
│EXIT     │   │                 VESSEL      REMOTE   │
└─────────┘   │      Status     ON          ON       │
              │      Vector To  POSITION # 50  VESSEL│
              │                                      │
              └──────────────────────────────────────┘

┌──────────────────────────────────┐
│                                  │
│                VESSEL   REMOTE   │
│      Status     OFF      OFF     │
│      Start Waypoint              │
│      End Waypoint                │
│      Switch Radius   5       5   │
│                                  │
└──────────────────────────────────┘
```

1. NAVAIDS PERFORMS CALCULATIONS ON NAVIGATION AND TRACKING DATA FOR
THE PURPOSE OF DETERMINING MAKING GOOD, VECTORING, AND WAYPOINT
NAVIGATION INFORMATION. MAKING GOOD AND VECTORING DATA IS DISPLAYED
ON THE MAIN NAVIGATION TEXT SCREEN. MAKING GOOD REPORTS SUCH INFORMATION
AS OFFSET AND CLOSING RATE DATA FROM A SELECTED TRACK LINE OR WAYPOINT.

2. VECTORING PROVIDES RANGE, BEARING AND TIME-TO-GO INFORMATION FOR THE
VESSEL AND/OR REMOTE ROV FOR CURRENT POSITION TO SELECTED POSITION,
BETWEEN THE VESSEL AND REMOTE ROV, OR TO THE START OF A WAYPOINT.

3. WAYPOINT NAVIGATION IS USED TO ENABLE THIS FEATURE FOR EITHER THE
VESSEL OR REMOTE AND SELECT THE STARTING AND ENDING WAYPOINT TO BE USED.

```
┌─────────┐    ┌──────────────┐        ┌──────────┐
│MISSION  │    │Data Logging  │ <<     │ FIXES    │
│OP_AREA  │    └──────────────┘        │ SECONDS  │
│SETUP    │                            │ FEET     │
│DEVICES  │                            └──────────┘
│NAVAIDS  │
│RATES    │ <<
│MISC     │
│EXIT     │
└─────────┘
```

┌───┐
│   System Data Logging   │
├───┤
│   │
│   System Logging   OFF   │
│   │
│   VESSEL   REMOTE   │
│   Units   FIXES   FIXES   │
│   Disk Store   5   5   NEW DISK   │
│   Plotter   0   0   NEW PLOT   │
│   Printer   0   0   │
│   │
└───┘

1. THE SYSTEM DATA LOGGING MENU ACTIVATES OUTPUT SERIAL AND PARALLEL PORTS FOR LOGGING NAVIGATION DATA TO THE PLOTTER OR PRINTER. A DATA OUTPUT CHANNEL IS ALSO OPENED TO STORE DATA TO A COMPUTER DISK FILE. SYSTEM LOGGING IS TURNED ON/OFF BY HIGHLIGHTING THE SYSTEM LOGGING OPTION.

2. THE UNITS POP-UP MENU DETERMINES WHETHER NAVIGATION DATA WILL BE LOGGED AFTER A PREDETERMINED NUMBER OF FIXES, SECONDS, OR FEET HAVE ELASPED. THE FREQUENCY OF THE LOGGING CAN BE ENTERED FOR EACH OF THE LOGGING DEVICES INDEPENDENTLY.

3. THE NEW DISK OPTION ALLOWS FOR APPENDING OF NEW DATA TO AN OLD DATA FILE OR OVERWRITING OF EXISTING DATA. THE NEW PLOT OPTION IS SELECTED WHEN A NEW SHEET OF PAPER IS PLACED ON THE PLOTTER. NEW PLOT PLACES A NEW LEGEND, GRID LINES AND ANY POSITION, BLOCKS, AND TRACKS ON THE BLANK PAPER.

```
┌──────────┐   ┌─────────────────────┐
│ MISSION  │   │ Heading Source  <<  │
│ OP_AREA  │   │ Radius Alarm        │
│ SETUP    │   │ Dead Reckoning      │
│ DEVICES  │   └─────────────────────┘
│ NAVAIDS  │
│ RATES    │
│ MISC  << │
│ EXIT     │
└──────────┘
```

HEADING SOURCE SUBMENU

```
┌──────────────────────────────────────┐
│                                       │
│          VESSEL         REMOTE        │
│  Source   NONE           COG          │
│  Adjust   0.0            0.0          │
│                                       │
└──────────────────────────────────────┘
```

VESSEL   SUBMERSIBLE
HEADING SOURCE   HEADING SOURCE

```
┌────────────┐   ┌──────────┐
│ NONE       │   │ NONE     │
│ COG        │   │ COG      │
│ HONEYWELL  │   └──────────┘
│ TRIMBLE    │
└────────────┘
```

DEAD RECKONING SUB-MENU

```
┌──────────────────────────────────────────┐
│ Dead Reckon Remote Vehicle On Missed Fixes? │
├──────────────────────────────────────────┤
│ No                                         │
│ Yes                                        │
└──────────────────────────────────────────┘
```

1. MISCELLANEOUS NAVIGATION FEATURES INCLUDE SELECTING THE SOURCE
FOR SHIP/REMOTE HEADING INFORMATION, ENABLING A RADIUS ALARM, AND
ACTIVATING/DE-ACTIVATING REMOTE DEAD RECKONING CAPABILITIES. VESSEL
AND/OR REMOTE HEADING OPTIONS AVAILIBLE ARE SELECTED FROM THE ABOVE
POP-UP MENUES. ADJUSTMENTS TO HEADING DATA CAN BE MADE FROM THE
HEADING SOURCE SUB-MENU.

2. REMOTE VEHICLE DEAD RECKONING IS POSSIBLE BY SELECTING YES FROM
ITS SUB-MENU. THIS FEATURE ALLOWS TRACKING BY DEAD RECKONING METHODS
IF THREE CONSECUTIVE FIXES ARE MISSED. IF TRACKING IS RESTORED THEN
DEAD RECKONING IS AUTOMATICALLY DISABLED.

```
┌────────────┐   ┌──────────────────────┐
│MISSION     │   │ Exit Seatrac?        │
│OP_AREA     │   ├──────────────────────┤
│SETUP       │   │No                    │
│DEVICES     │   │Yes                   │
│NAVAIDS     │   │                      │
│RATES       │   └──────────────────────┘
│MISC        │
│EXIT        │ <<
└────────────┘
```

1. EXITING THE SEATRAC PROGRAM SHOULD BE CONDUCTED USING THE "EXIT SEATRAC"
MENU. THIS WILL ASSURE THAT ALL DATA FILES ARE CLOSED PROPERLY, AND
NO RECORDED DATA WILL BE LOST.

APPENDIX B

SAMPLE DATA FILES

This appendix consists of excerpts from transponder network calibration and navigation data files. The examples included are intended to serve as a guide for creating the proper operating environment prior to executing the various calibration and navigation programs. Various data files may require additional tailoring depending upon the specific application. Data files created as a result of program execution may be compared to the sample files contained herein to verify correct system operation.

TYPICAL NS011-XX.YYY DATA FILE
GENERATED BY AUSSCALB.EXE PROGRAM

TIME AFTER MID NIGHT (SECONDS)	SLANT RANGE1 (YARDS)	SLANT RANGE2 (YARDS)	SLANT RANGE3 (YARDS)	SLANT RANGE4 (YARDS)
8 5				
3.3358000E+04	1.8809385E+03	2.4453260E+03	-1.0000000E-01	-1.0000000E-01
3.3388000E+04	1.8667575E+03	2.4359535E+03	-1.0000000E-01	-1.0000000E-01
3.3398000E+04	1.8619490E+03	-1.0000000E-01	-1.0000000E-01	-1.0000000E-01
3.3428000E+04	1.8468715E+03	2.4325305E+03	-1.0000000E-01	-1.0000000E-01
3.3438000E+04	1.8419815E+03	-1.0000000E-01	-1.0000000E-01	-1.0000000E-01
3.3448000E+04	1.8374175E+03	2.4070210E+03	-1.0000000E-01	-1.0000000E-01
3.3458000E+04	1.8334240E+03	-1.0000000E-01	-1.0000000E-01	-1.0000000E-01
3.3468000E+04	1.8291045E+03	-1.0000000E-01	-1.0000000E-01	-1.0000000E-01

NOTES: 1. THE FIRST LINE OF THE DATA FILE CONSISTS OF THE LINE "8 5". THIS ENTRY OF THE DATA FILE SPECIFIES THE NUMBER OF LINE ENTRIES IN THE FILE AND THE NUMBER OF COLUMN ENTRIES PER LINE. FOR EXAMPLE THE DATA FILE ABOVE CONSISTS OF EIGHT LINES OF DATA WITH FIVE COLUMN ENTRIES PER LINE.

2. COLUMN ONE IS THE TIME AFTER MIDNIGHT LOCAL TIME THE DATA WAS RECORDED BY THE NS011. COLUMNS 2 THRU 5 ARE SLANT RANGES BETWEEN THE SURFACE SHIP AND TRANSPONDER COMPUTED FROM ROUND TRIP TRAVEL TIMES MEASURED BY THE NS011. ONLY ONE SLANT RANGE OF THE FOUR REPRESENTS THE DIRECT PATH BETWEEN THE SURFACE SHIP AND TRANSPONDER. ALL OTHER ENTRIES ARE DUE TO MULTIPATH SIGNALS. A NEGATIVE NUMBER IN COLUMNS TWO THRU FOUR REPRESENT NON-VALID DATA.

TYPICAL BUOYxx.YYY DATA FILE
GENERATED BY FIXSUMMA.EXE PROGRAM

TIME AFTER MID NIGHT (SECONDS)	SLANT RANGE1 (YARDS)	SLANT RANGE2 (YARDS)	SLANT RANGE3 (YARDS)	SLANT RANGE4 (YARDS)
8 5				
3.557800E+04	2.0256825E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.558800E+04	2.0162285E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.559800E+04	2.0053075E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.560800E+04	1.9922675E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.561800E+04	1.9773530E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.562800E+04	1.9621125E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.563800E+04	1.9465460E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04
3.564800E+04	1.9311425E+03	-1.0000000E+04	-1.0000000E+04	-1.0000000E+04

NOTES: 1. THE FIRST LINE OF THE DATA FILE CONSISTS OF THE LINE "8 5". THIS
ENTRY OF THE DATA FILE SPECIFIES THE NUMBER OF LINE ENTRIES IN THE
FILE AND THE NUMBER OF COLUMN ENTRIES PER LINE. FOR EXAMPLE THE DATA
FILE ABOVE CONSISTS OF EIGHT LINES OF DATA WITH FIVE COLUMN ENTRIES
PER LINE.

2. COLUMN ONE IS THE TIME AFTER MIDNIGHT LOCAL TIME THE DATA WAS
RECORDED BY THE NS011. COLUMNS 2 THRU 5 ARE SLANT RANGES BETWEEN THE
SURFACE SHIP AND TRANSPONDER COMPUTED FROM ROUND TRIP TRAVEL TIMES
MEASURED BY THE NS011. COLUMN TWO IS THE ONLY COLUMN THAT SHOULD
HAVE VALID SLANT RANGE DATA AS THE RESULT OF EXECUTING FIXSUMMA.EXE
PROGRAM. COLUMNS THREE THRU FIVE SHOULD HAVE NEGATIVE NUMBERS.

B-3

TYPICAL RANGES.XXX DATA FILE
GENERATED BY SHUFFLE.EXE PROGRAM

TIME AFTER MID NIGHT (SECONDS)	SLANT RANGE TRANSPONDER1 (YARDS)	SLANT RANGE TRANSPONDER2 (YARDS)	SLANT RANGE TRANSPONDER3 (YARDS)	SLANT RANGE TRANSPONDER4 (YARDS)
8 5				
4.1748000E+04	1.3064726E+03	1.5030608E+03	1.4034691E+03	1.0374614E+03
4.1758000E+04	1.3091489E+03	1.4993301E+03	1.3991707E+03	1.0394890E+03
4.1768000E+04	1.3124740E+03	1.4954373E+03	1.3940614E+03	1.0413543E+03
4.1778000E+04	1.3158803E+03	1.4928421E+03	1.3892764E+03	1.0434629E+03
4.1788000E+04	1.3204219E+03	1.4906524E+03	1.3837616E+03	1.0444361E+03
4.1798000E+04	1.3246391E+03	1.4887870E+03	1.3784900E+03	1.0457337E+03
4.1808000E+04	1.3295863E+03	1.4867595E+03	1.3721642E+03	1.0462203E+03
4.1818000E+04	1.3348578E+03	1.4862729E+03	1.3663249E+03	1.0463014E+03

NOTES: 1. THE FIRST LINE OF THE DATA FILE CONSISTS OF THE LINE "8 5". THIS ENTRY OF THE DATA FILE SPECIFIES THE NUMBER OF LINE ENTRIES IN THE FILE AND THE NUMBER OF COLUMN ENTRIES PER LINE. FOR EXAMPLE THE DATA FILE ABOVE CONSISTS OF EIGHT LINES OF DATA WITH FIVE COLUMN ENTRIES PER LINE.

2. COLUMN ONE IS THE TIME AFTER MIDNIGHT LOCAL TIME THE DATA WAS RECORDED BY THE NS011. COLUMNS 2 THRU 5 ARE DIRECT PATH SLANT RANGES BETWEEN THE EACH NETWORK TRANSPONDER AND THE SURFACE SHIP CORRECTED FOR TRANSPONDER TURNAROUND TIME, AND RAYBENDING IF APPLICABLE

3. THE ABOVE DATA FILE IS FOR A FOUR TRANSPONDER NETWORK. AN ADDITIONAL SLANT RANGE COLUMN IS GENERATED FOR EACH ADDITIONAL TRANSPONDER DEPLOYED IN THE NETWORK.

TYPICAL SOLUTS.XXX DATA FILE
GENERATED BY LBLNAV.EXE PROGRAM

TIME AFTER MIDNIGHT (SECONDS)	SHIP'S TRACK X COORDINATE LBL SOLUTION (LAMBERT ZN6 YARDS)	SHIP'S TRACK Y COORDINATE LBL SOLUTION (LAMBERT ZN6 YARDS)	XDUCER DEPTH (YARDS)	# OF XPONDERS	RMS ERROR (YARDS)
8 6					
3.3358000E+04	5.3810598E+05	9.8454616E+04	4.0E+00	4.00E+00	9.201030E-01
3.3388000E+04	5.3810161E+05	9.8486264E+04	4.0E+00	4.00E+00	1.014206E+00
3.3398000E+04	5.3810068E+05	9.8496465E+04	4.0E+00	4.00E+00	5.246973E-01
3.3428000E+04	5.3809418E+05	9.8528370E+04	4.0E+00	4.00E+00	7.623752E-01
3.3438000E+04	5.3809209E+05	9.8539021E+04	4.0E+00	4.00E+00	8.793266E-01
3.3448000E+04	5.3809041E+05	9.8549520E+04	4.0E+00	4.00E+00	1.035336E+00
3.3458000E+04	5.3808947E+05	9.8560614E+04	4.0E+00	4.00E+00	8.739183E-01
3.3468000E+04	5.3808820E+05	9.8571750E+04	4.0E+00	4.00E+00	9.657289E-01

NOTES: 1. THE SOLUTES DATA FILE CONSISTS OF COMPUTED SHIP'S LONG BASELINE
TRACK AND POSITION ERROR COMPUTED FOR EACH FIX. THE SHIP'S X,Y
POSITIONS ARE COMPUTED IN LAMBERT CALIFORNIA ZONE 6 STATE PLANE
COORDINATES. THE SHIP'S TRACK IS COMPUTED USING RELATIVE TRANSPONDER
POSITIONS AT THIS STAGE IN THE NETWORK CALIBRATION PROCEDURE. THE
ABOVE X,Y POSITIONS REQUIRE TRANSLATION AND ROTATION FOR ALIGNMENT
WITH ABSOLUTE GEODETIC COORDINATES.

TYPICAL SURFACE NAVIGATION DATA FILE
GENERATED BY AUSSCALB.EXE PROGRAM

TIME AFTER MIDNIGHT (SECONDS)	SHIP'S TRACK X COORDINATE GPS SOLUTION (LAMBERT ZN6 YARDS)	SHIP'S TRACK Y COORDINATE GPS SOLUTION (LAMBERT ZN6 YARDS)	SHIP'S HEADING (DEGREES) *

8 4

3.335800000E+04	5.381079979E+05	9.844837847E+04	0.000000000E+00
3.338800000E+04	5.381066598E+05	9.847871654E+04	0.000000000E+00
3.339800000E+04	5.381067817E+05	9.848882239E+04	0.000000000E+00
3.342800000E+04	5.380986774E+05	9.852328500E+04	0.000000000E+00
3.343800000E+04	5.380953674E+05	9.853141077E+04	0.000000000E+00
3.344800000E+04	5.380921062E+05	9.854357889E+04	0.000000000E+00
3.345800000E+04	5.380888450E+05	9.855574700E+04	0.000000000E+00
3.346800000E+04	5.380889669E+05	9.856585284E+04	0.000000000E+00

NOTES: 1. THE SURFACE NAVIGATION DATA FILE CONSISTS OF POSITION FIXES IN
LAMBERT CALIFORNIA ZONE 6 STATE PLANE COORDINATES. SURFACE FIXES
ARE RECORDED FOR EACH INTERROGATION OF THE LONG BASELINE NETWORK
CONDUCTED DURING CALIBRATION RUNS. THIS DATA FILE IS USED TO
DETERMINE THE REQUIRED TRANSLATION AND ROTATION OF THE SHIP'S
LBL TRACK SO THAT IT ALIGNS WITH THE SURFACE NAVIGATION TRACK.
THE CALCULATED TRANSLATION AND ROTATION PARAMETERS ARE THEN APPLIED
TO THE RELATIVE TRANSPONDER POSITIONS RECORDED IN THE XPONPOS DATA
FILE. THIS PROCESS RESULTS IN TRANSPONDER COORDINATES THAT ARE
CALIBRATED IN ABSOLUTE GEODETIC TERMS.

2. (*) SHIP'S HEADING WAS NOT RECORDED FOR THIS CALIBRATION RUN.

FIRSTFIX DATA FILE

LAMBERT CAL ZN6 X (YARDS)		LAMBERT CAL ZN6 Y (YARDS)
537246		99804

THE ABOVE NUMBERS REPRESENT X,Y LAMBERT CALIFORNIA ZONE 6 STATE PLANE
COORDINATES IN YARDS. THE COORDINATES ARE USED BY THE TRANSPONDER NETWORK
CALIBRATION ROUTINES AS AN INITIAL GUESS OF THE SHIPS POSITION FOR THE
PURPOSE OF CALCULATING TRANSPONDER SLANT RANGE.

- -

XPONPOS DATA FILE (ASCII CONVERSION OF BINARY FILE)

TRANSPONDER LAMBERT CALIFORNIA ZONE 6 X COORDINATE (YARDS)	TRANSPONDER LAMBERT CALIFORNIA ZONE 6 Y COORDINATE (YARDS)	TRANSPONDER DEPTH (YARDS)
8 3		
5.355565818439079E+05	1.007384328630557E+05	8.000000000000000E+02
5.390078056094887E+05	1.010932058970434E+05	8.000000000000000E+02
5.382478443802543E+05	1.012162117026924E+05	8.000000000000000E+02
5.363128432434982E+05	1.003805570862548E+05	8.000000000000000E+02
5.354391293411802E+05	1.006894816981992E+05	8.000000000000000E+02
5.390517293538558E+05	1.010812397516746E+05	8.000000000000000E+02
5.382628798425918E+05	1.012522423444654E+05	8.000000000000000E+02
5.379404925011961E+05	9.914582329251629E+04	8.000000000000000E+02

THE ABOVE DATA REPRESENT X,Y,Z LAMBERT CALIFORNIA ZONE 6 COORDINATES OF
AN 8 TRANSPONDER NETWORK. INITIALLY THE COORDINATES REPRESENT THE SURFACE
DEPLOYMENT POSITIONS OF THE TRANSPONDERS. AFTER THE TRANSPONDER NETWORK
CALIBRATION PROCESS IS COMPLETE, THE DATA WILL BE MODIFIED TO REFLECT THE
ABSOLUTE TRANSPONDER POSITIONS IN LAMBERT COORDINATES.

- -

TURNARND DATA FILE

```
8 2
1 3.0
2 3.0
3 3.0
4 3.0
5 3.0
6 3.0
7 3.0
8 3.0
```

THE TURNARND DATA FILE CONSISTS OF 2 COLUMNS OF DATA. THE FIRST COLUMN IS
THE ASSIGNED NETWORK TRANSPONDER NUMBER. COLUMN TWO IS THE TRANSPONDER
TURN AROUND TIME IN MILLISECONDS. TURN AROUND IS DEFINED AS THE AMOUNT OF
TIME IT TAKES THE TRANSPONDER TO ISSUE A RESPOND PING WHEN INTERROGATED
FROM AN EXTERNAL SOURCE. THIS FILE IS REQUIRED BY THE CALIBRATION ROUTINE
SHUFFLE.EXE TO CORRECT TRANSPONDER SLANT RANGES.

MAXRANGE DATA FILE

```
8 2
1 5000
2 5000
3 5000
4 5000
5 5000
6 5000
7 5000
8 5000
```

THE MAXRANGE DATA FILE CONSISTS OF TWO COLUMNS OF DATA. THE FIRST COLUMN IS
THE ASSIGNED NETWORK TRANSPONDER NUMBER. COLUMN TWO IS THE MAXIMUM TRANSPONDER
SLANT RANGE IN YARDS THE CALIBRATION ROUTINES WILL ACCEPT IN CALIBRATING THE
NETWORK. THIS FILE SERVES AS AN INPUT FILTER FOR THE SHUFFLE.EXE PROGRAM.

APPENDIX C

SAMPLE SYSTEM CONFIGURATION SETUPS

This appendix consists of system configuration setups for the Honeywell RS906 underwater tracking system and the Trimble 10X LORAN/GPS surface navigator. The steps listed for each piece of hardware have been tailored for a typical AUSS search operation. Setup parameters will vary depending upon specific system operation requirements.

HONEYWELL RS906 ACOUSTIC TRACKING SYSTEM
SYSTEM SETUP FOR LBS AND SBS
OPERATION

1.   GRAPHICS DISPLAY ----- UNITS FEET
     RETURN

2.   MODE SELECT ----- TEST MODE ----- SPECIAL TESTS
     SYSTEM SETUP.......................................9534 ENTER
     HYD 1 DATA INPUT ----- X OFFSET...................   0 ENTER
     Y OFFSET..   0 ENTER
     Z OFFSET..   0 ENTER
     ASIMUTH OFFSET....................................180.0 ENTER
     F/A TILT OFFSET................................... 0.7 ENTER
     P/S TILT OFFSET................................... 0.8 ENTER
     ALL OTHER ENTRIES................................. 0.0 ENTER
     RETURN ONE LEVEL

3.   CONTINUE ----- RS232 1 SETUP..................... 237 ENTER
     RETURN TO TOP LEVEL

4.   OTHER DATA IN -- ALARM SILENCE -- HYDR 1 TEMP....   0 ENTER
     MAXIMUM RANGE.....................................7500 ENTER
     SYSTEM SOUND VELOCITY.............................4882 ENTER
     CONTINUE ----- DIGITAL RECORDING "ON"
     RETURN ONE LEVEL

5.   OTHER DATA IN ----- CONTINUE ----- SUBMERS REFERENCE
     LBS BEACON..   6 ENTER
     RETURN TOP LEVEL

6.   EXTERNAL DEPTH SCALE
     DEPTH 1 RANGE.....................................2500 ENTER
     DEPTH 1 BIAS......................................   0 ENTER
     RETURN ONE LEVEL

7.   SUBMARINE REFERENCE...............................   6 ENTER
     RETURN TOP LEVEL

8.   MODE SELECT ----- LBS CALIBRATE ----- GOTO CALIBRATE
     BCN CAL SEQUENCE ----- REFERENCE 1 BEACON........   1 ENTER
     REFERENCE 2 BEACON................................   2 ENTER
     REFERENCE 3 BEACON................................   3 ENTER
     REFERENCE 4 BEACON................................   4 ENTER
     RETURN TOP LEVEL

9.   LBS RECEIVER ----- CONTINUE ----- RANGE GATE "OFF"
     RESTORE CAL DATA ----- CALIBRATE GRID COORD
     CAL COORD DISPLAY ----- SELECT BEACON NO.........   1 ENTER
     X CAL COORD.......................................   0 ENTER
     Y CAL COORD.......................................   0 ENTER
     Z CAL COORD.......................................2354 ENTER
     SELECT BEACON NO..................................   2 ENTER
     X CAL COORD.......................................4090 ENTER
     Y CAL COORD.......................................   0 ENTER
     Z CAL COORD.......................................2303 ENTER
     SELECT BEACON NO..................................   3 ENTER
     X CAL COORD.......................................4060 ENTER
     Y CAL COORD.......................................4044 ENTER

C-2

```
Z CAL COORD................................................2277 ENTER
SELECT BEACON NO...........................................   4 ENTER
X CAL COORD................................................ -34 ENTER
Y CAL COORD................................................3975 ENTER
Z CAL COORD................................................2336 ENTER
RETURN TO TOP LEVEL
```

```
10.   LBS RECEIVER ----- CONTINUE ----- LBS GRID CENTER
      LBS X CENTER.........................................2100 ENTER
      LBS Y CENTER.........................................2050 ENTER
      LBS Z CENTER.........................................   0 ENTER
      LBS GRID BEARING..................................... 359 ENTER
      STORE BCN OFFSETS.................................... 747 ENTER
      RETURN TO TOP LEVEL
```

```
11.   LBS RECEIVER ----- BEACON SELECTION
      BEACON RECEIVER 1....................................   1 ENTER
      BEACON RECEIVER 2....................................   2 ENTER
      BEACON RECEIVER 3....................................   3 ENTER
      BEACON RECEIVER 4....................................   4 ENTER
      BEACON RANGE 1.......................................   1 ENTER
      BEACON RANGE 2.......................................   2 ENTER
      BEACON RANGE 3.......................................   3 ENTER
      BEACON RANGE 4.......................................   4 ENTER
```

```
12.   BEACON DATA IN. (LBS #1).............................   1 ENTER
      BEACON CODE..............................100232636000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS ----- BEACON TYPE ----- "TRANSPONDER"
      INT PULSE WIDTH......................................  10 ENTER
      TRANSPONDER DELAY....................................   3 ENTER
      RETURN TO TOP LEVEL

            note: interrogate ch 6;   reply ch 32
```

```
13.   BEACON DATA IN. (LBS #2).............................   2 ENTER
      BEACON CODE..............................100233636000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS ----- BEACON TYPE ----- "TRANSPONDER"
      INT PULSE WIDTH......................................  10 ENTER
      TRANSPONDER DELAY....................................   3 ENTER
      RETURN TO TOP LEVEL

            note: interrogate ch 6;   reply ch 33
```

```
14.   BEACON DATA IN. (LBS #3).............................   3 ENTER
      BEACON CODE..............................100234636000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS ----- BEACON TYPE ----- "TRANSPONDER"
      INT PULSE WIDTH......................................  10 ENTER
      TRANSPONDER DELAY....................................   3 ENTER
      RETURN TO TOP LEVEL

            note: interrogate ch 6;   reply ch 34
```

```
15.   BEACON DATA IN. (LBS #4)..........................      4 ENTER
      BEACON CODE.............................100235636000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS ----- BEACON TYPE ----- "TRANSPONDER"
      INT PULSE WIDTH..................................     10 ENTER
      TRANSPONDER DELAY...............................      3 ENTER
      RETURN TO TOP LEVEL

          note: interrogate ch 6;   reply ch 35

16.   BEACON DATA IN. (YELLOW BANANA)..................      5 ENTER
      BEACON CODE.............................100236635000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS ----- BEACON TYPE ----- "TRANSPONDER"
      INT PULSE WIDTH..................................     10 ENTER
      TRANSPONDER DELAY......... ...............       5 ENTER
      RETURN TO TOP LEVEL

          note: interrogate ch 5;   reply ch 36

17.   BEACON DATA IN. (STINGER)........................      6 ENTER
      CONTINUE ----- EXPANDED BEACON DATA
      SPECIAL INPUTS --- BEACON TYPE --- "SUBREPEATER"
      REPLY CHANNEL 1.................................     23 ENTER
      REPLY PULSE WIDTH..............................      5 ENTER
      INTERROGATE CHANNEL............................      5 ENTER
      INT PULSE WIDTH................................     25 ENTER
      INT PHASE CODE................................    255 ENTER
      TRANSPONDER DELAY.............................   -0.9 ENTER
      REPEATER SUBDELAY.............................   -0.9 ENTER
      RETURN TO TOP LEVEL

18.   BEACON DATA IN. (DESCENT WEIGHT BURN)...........      7 ENTER
      BEACON CODE.............................100238636000 ENTER
      CONTINUE ---- EXPANDED BEACON DISP
      SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
      INT PULSE WIDTH................................     10 ENTER
      TRANSPONDER DELAY.............................    4.6 ENTER
      RETURN TO TOP LEVEL

          note: interrogate ch 6;   reply ch 38

19.   BEACON DATA IN. (SBS FOR LBS #1).................     11 ENTER
      BEACON CODE.............................100232636000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
      INT PULSE WIDTH................................     10 ENTER
      TRANSPONDER DELAY.............................      3 ENTER
      RETURN TO TOP LEVEL

          note: interrogate ch 6;   reply ch 32
```

20. BEACON DATA IN. (SBS FOR LBS #2)............... 12 ENTER
     BEACON CODE.............................100233636000 ENTER
     CONTINUE ----- EXPANDED BEACON DISP
     SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
     INT PULSE WIDTH.................................. 10 ENTER
     TRANSPONDER DELAY................................ 3 ENTER
     RETURN TO TOP LEVEL

          note: interrogate ch 6; reply ch 33

21. BEACON DATA IN. (SBS FOR LBS #3)............... 13 ENTER
     BEACON CODE.............................100234636000 ENTER
     CONTINUE ----- EXPANDED BEACON DISP
     SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
     INT PULSE WIDTH.................................. 10 ENTER
     TRANSPONDER DELAY................................ 3 ENTER
     RETURN TO TOP LEVEL

          note: interrogate ch 6; reply ch 34

22. BEACON DATA IN. (SBS FOR LBS #4)............... 14 ENTER
     BEACON CODE.............................100235636000 ENTER
     CONTINUE ----- EXPANDED BEACON DISP
     SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
     INT PULSE WIDTH.................................. 10 ENTER
     TRANSPONDER DELAY................................ 3 ENTER
     RETURN TO TOP LEVEL
     note: interrogate ch 6; reply ch 35

23. BEACON DATA IN. (NT020 BURN WIRE RESPONSE)...... 20 ENTER
     BEACON CODE.............................100236636000 ENTER
     CONTINUE ----- EXPANDED BEACON DISP
     SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
     INT PULSE WIDTH.................................. 10 ENTER
     TRANSPONDER DELAY.............................204.6 ENTER
     RETURN TO TOP LEVEL

          note: interrogate ch 6; reply ch 36

24. BEACON DATA IN.................................... 8 ENTER
     DEPTH SOURCE ----- EXT DEPTH SENSOR 1
     CONTINUE ----- EXPANDED BEACON DISP
     SPECIAL INPUTS ----- BEACON TYPE ----- "PINGER"
     REPLY CHANNEL.................................... 33 ENTER
     REPLY PULSE WIDTH................................ 5 ENTER
     PULSE REP PERIOD................................ 700 ENTER
     RETURN TO TOP LEVEL

25. BEACON DATA IN "TEST PINGER DECK CHECK" (9 KHz). 9 ENTER
     DEPTH SOURCE ----- KEYBOARD INPUT............... 50 ENTER
     CONTINUE ----- EXPANDED BEACON DISP
     SPECIAL INPUTS ----- BEACON TYPE ---- "PINGER"
     REPLY CHANNEL.................................... 27 ENTER
     REPLY PULSE WIDTH................................ 5 ENTER
     PULSE REP PERIOD............................... 900 ENTER
     RETURN TO TOP LEVEL

26. SBS1 RECEIVER ----- HYDROPHONE ----- HYDR1 PRECISION
    RETURN 1 LEVEL

27. HEADING INPUT ----- GYRO 1 ----- CONTINUE
    RANGE GATE OFF ----- FILTER OFF
    RETURN TO TOP LEVEL

28. SBS2 RECEIVER ----- HYDROPHONE ----- HYDR1 PRECISION
    RETURN 1 LEVEL

29. HEADING INPUT ----- GYRO 1 ----- CONTINUE
    RANGE GATE OFF ----- FILTER OFF
    RETURN TO TOP LEVEL

30. GRAPHIC DISPLAY --- GRID COORD --- LBS DIFF POSITION
    NORMAL FUNCTION --- SUPPRESS LBS GRID "OFF"
    RETURN 1 LEVEL

31. DISPLAY SCALE...................................2500 ENTER
    POSITION MONITOR................................   0 ENTER
    GRID HEADING....................................   0 ENTER
    RETURN TO TOP LEVEL

32. LBS RECEIVER ----- HEADING INPUT ----- GYRO 1
    RETURN TO TOP LEVEL

33. BEACON ASSIGNMENTS (SBS)
    BEACON 5 "SBS2B AUSS XPONDER"
    FISH CYCLE
    BEACON 6 "SBS1A SUB REPEATER"
    RETURN TO TOP LEVEL

34. DATA DISPLAY ----- OPERATIONAL
    RETURN TO TOP LEVEL

35. MODE SELECT ----- INTERROGATE PERIOD............   6 ENTER

        interrogate channels   reply channels
        --------------------   --------------
            5.....9KHz   21.....6.0KHz
            6.....7KHz   22.....6.5KHz
                                              23.....7.0KHz
                                              24.....7.5KHz
                                              25.....8.0KHz
                                              26.....8.5KHz
                                              27.....9.0KHz
                                              28.....9.5KHz
                                              29....10.0KHz
                                              30....10.5KHz
                                              31....11.0KHz
                                              32....11.5KHz
                                              33....12.0KHz
                                              34....12.5KHz
                                              35....13.0KHz
                                              36....13.5KHz
                                              37....14.0KHz
                                              38....14.5KHz
                                              39....15.0KHz

HONEYWELL RS906 ACOUSTIC TRACKING SYSTEM
SYSTEM SETUP FOR SBS OPERATION

1. GRAPHICS DISPLAY ----- UNITS FEET
   RETURN

2. MODE SELECT ----- TEST MODE ----- SPECIAL TESTS
   SYSTEM SETUP......................................9534 ENTER
   HYD 1 DATA INPUT ----- X OFFSET...................   0 ENTER
   Y OFFSET..   0 ENTER
   Z OFFSET..   0 ENTER
   ASIMUTH OFFSET....................................180.0 ENTER
   F/A TILT OFFSET................................... 0.7 ENTER
   P/S TILT OFFSET................................... 0.8 ENTER
   ALL OTHER ENTRIES................................. 0.0 ENTER
   RETURN ONE LEVEL

3. CONTINUE ----- RS232 1 SETUP..................... 237 ENTER
   RETURN TO TOP LEVEL

4. OTHER DATA IN -- ALARM SILENCE -- HYDR 1 TEMP....   0 ENTER
   MAXIMUM RANGE.....................................7500 ENTER
   SYSTEM SOUND VELOCITY.............................4882 ENTER
   CONTINUE ----- DIGITAL RECORDING "ON"
   RETURN ONE LEVEL

5. OTHER DATA IN ----- CONTINUE ----- SUBMERS REFERENCE
   LBS BEACON..   6 ENTER
   RETURN TOP LEVEL

6. EXTERNAL DEPTH SCALE
   DEPTH 1 RANGE.....................................2500 ENTER
   DEPTH 1 BIAS......................................   0 ENTER
   RETURN ONE LEVEL

7. BEACON DATA IN. (YELLOW BANANA).................   5 ENTER
   BEACON CODE.............................100236635000 ENTER
   CONTINUE ----- EXPANDED BEACON DISP
   SPECIAL INPUTS ----- BEACON TYPE ---- "TRANSPONDER"
   INT PULSE WIDTH................................... 10 ENTER
   TRANSPONDER DELAY.................................   5 ENTER
   RETURN TO TOP LEVEL

        note: interrogate ch 5;   reply ch 36

8. BEACON DATA IN. (STINGER).......................   6 ENTER
   CONTINUE ----- EXPANDED BEACON DATA
   SPECIAL INPUTS --- BEACON TYPE --- "SUBREPEATER"
   REPLY CHANNEL 1................................... 23 ENTER
   REPLY PULSE WIDTH.................................   5 ENTER
   INTERROGATE CHANNEL...............................   5 ENTER
   INT PULSE WIDTH................................... 25 ENTER
   INT PHASE CODE.................................... 255 ENTER
   TRANSPONDER DELAY................................. -0.9 ENTER
   REPEATER SUBDELAY................................. -0.9 ENTER
   RETURN TO TOP LEVEL

```
9.    BEACON DATA IN. (DESCENT WEIGHT BURN)............    7 ENTER
      BEACON CODE................................100238636000 ENTER
      CONTINUE ---- EXPANDED BEACON DISP
      SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
      INT PULSE WIDTH....................................   10 ENTER
      TRANSPONDER DELAY.................................   4.6 ENTER
      RETURN TO TOP LEVEL

            note: interrogate ch 6;   reply ch 38


10.   BEACON DATA IN. (NT020 BURN WIRE RESPONSE)......   20 ENTER
      BEACON CODE................................100236636000 ENTER
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS --- BEACON TYPE --- "TRANSPONDER"
      INT PULSE WIDTH....................................   10 ENTER
      TRANSPONDER DELAY.............................204.6 ENTER
      RETURN TO TOP LEVEL

            note: interrogate ch 6;   reply ch 36

11.   BEACON DATA IN...................................    8 ENTER
      DEPTH SOURCE ----- EXT DEPTH SENSOR 1
      CONTINUE ----- EXPANDED BEACON DISP
      SPECIAL INPUTS ----- BEACON TYPE ----- "PINGER"
      REPLY CHANNEL.....................................   33 ENTER
      REPLY PULSE WIDTH.................................    5 ENTER
      PULSE REP PERIOD.................................  700 ENTER
      RETURN TO TOP LEVEL

12.   SBS1 RECEIVER ----- HYDROPHONE ----- HYDR1 PRECISION
      RETURN 1 LEVEL

13.   HEADING INPUT ----- GYRO 1 ----- CONTINUE
      RANGE GATE OFF ----- FILTER OFF
      RETURN TO TOP LEVEL

14.   SBS2 RECEIVER ----- HYDROPHONE ----- HYDR1 PRECISION
      RETURN 1 LEVEL

15.   HEADING INPUT ----- GYRO 1 ----- CONTINUE
      RANGE GATE OFF ----- FILTER OFF
      RETURN TO TOP LEVEL

16.   GRAPHIC DISPLAY --- GRID COORD --- LBS DIFF POSITION
      NORMAL FUNCTION --- SUPPRESS LBS GRID "OFF"
      RETURN 1 LEVEL

17.   DISPLAY SCALE..................................2500 ENTER
      POSITION MONITOR..................................    0 ENTER
      GRID HEADING......................................    0 ENTER
      RETURN TO TOP LEVEL

18.   LBS RECEIVER ----- HEADING INPUT ----- GYRO 1
      RETURN TO TOP LEVEL
```

19. BEACON ASSIGNMENTS (SBS)
    BEACON 5 "SBS2B AUSS XPONDER"
    FISH CYCLE
    BEACON 6 "SBS1A SUB REPEATER"
    RETURN TO TOP LEVEL

20. DATA DISPLAY ····· OPERATIONAL
    RETURN TO TOP LEVEL

21. MODE SELECT ····· INTERROGATE PERIOD............ 10 ENTER

```
        interrogate channels                    reply channels
        --------------------                    -----------------
              5.....9KHz                          21.....6.0KHz
              6.....7KHz                          22.....6.5KHz
                                                  23.....7.0KHz
                                                  24.....7.5KHz
                                                  25.....8.0KHz
                                                  26.....8.5KHz
                                                  27.....9.0KHz
                                                  28.....9.5KHz
                                                  29....10.0KHz
                                                  30....10.5KHz
                                                  31....11.0KHz
                                                  32....11.5KHz
                                                  33....12.0KHz
                                                  34....12.5KHz
                                                  35....13.0KHz
                                                  36....13.5KHz
                                                  37....14.0KHz
                                                  38....14.5KHz
                                                  39....15.0KHz
```

TRIMBLE 10X LORAN/GPS
SYSTEM SETUP FOR
SURFACE NAVIGATION AND TRACKING

The following keystrokes entered at the Control Display Unit are required, as a minimum, to set up the Trimble 10X receiver for AUSS surface navigation operation. For specific receiver configuration changes or additions/deletions, the operator is referred to LORAN/GPS 10X NAVIGATOR Operators Manual 11653 Rev. D1 by TRIMBLE NAVIGATION.

```
               TRIMBLE 10X LORAN/GPS RECEIVER SETUP
      _____
               HARDWARE SETUP FOR SPS OR DIFFERENTIAL GPS OPERATION


     ON----CLEAR----SELECT----SENSOR----GPS (ON)----LORAN (OFF)
     S/H (OFF)----CLEAR----CLEAR


     INIT----*----*----GPS----ANT_HGT----(ENTER ANTENNA HEIGHT)
     DONE----CLEAR


     INIT----*----*----GPS----MASKS----ELEV----(ENTER ELEV MASK)
     DONE----CLEAR


     INIT----*----*----GPS----MASKS----SNR----(ENTER SNR MASK)
     DONE----CLEAR


     INIT----*----*----GPS----MASKS----PDOP----(ENTER PDOP MASK)
     DONE----CLEAR


     INIT----*----*----GPS----**----MODE----(2-D)----CLEAR----PDOP_SWCH
     (ENTER #)----DONE----CLEAR


     INIT----*----*----GPS----**----*----VEH_DYN----(SEA)----CLEAR
     **----**

     DIFF_GPS----(SELECT GPS,GPD,AUTO)----CLEAR----CLEAR----CLEAR


               HARDWARE SETUP FOR LORAN-C OPERATION


     ON----CLEAR----SELECT----SENORS----LORAN (ON)----GPS (OFF)
     S/H (OFF)----CLEAR----CLEAR

     INIT----*----LORAN----GRI----(ENTER GRI #)----CLEAR
```

```
INIT----*----*----*----*----*----*----RATE
(ENTER RATE)----CLEAR

I/O----**----**----NMEA_OUT#1----(ON)----NMEA_OUT#2----(ON)
NMEA_OUT#3----(OFF)----CLEAR----*

LOCAL-GMT----(ENTER OFFSET #)----CLEAR

INIT----*----*----*----*----*----*----*----*----*----UNITS
(NM)----CLEAR

*----DATUM----(** TO DISPLAY DATUMS AVAILABLE)----ENTER
CLEAR

*----GEOID----(AUTO)----*----SAIL MODE
GREAT_CIR----CLEAR----CLEAR

SELECT----**----CHANNEL----*----*----*----RTCM-104
(CH#3)----CLEAR----CODE----NMEA I/O CODES----OUT1
(04100000500)----ENTER----CLEAR

OUT2----(04000000000)----ENTER----CLEAR

OUT3----(37777777777)----ENTER----CLEAR----CLEAR----**
BAUD----CH----(CH#1)----BAUD----(4800)----CH----(CH#2)
BAUD----(4800)----CH----(CH#3)----BAUD----(4800)
CLEAR----CLEAR
```

DEFINITION OF ACRONYMS AND TERMS

ANT_HGT: (Antenna Height) Enters the GPS antenna height above the mean sea level.

BAUD: The rate at which data are exported out the three receiver I/O ports. Each channel can be configured for different baud rates.

DATUM: Sets the datum for LAT/LON display. Options are WGS84, NAD27 Alaska/Canada, European, Tokyo, Australian, WGS72, and NAD83.

DIFF GPS: Differential Global Positioning System.

GEOID: Determines whether local geoid corrections will be applied to the altitude in WGS84 datum.

GPS: Global Positioning System. The receiver operating in this mode uses SPS (Standard Positioning System).

GREAT_CIR: Divides the great circle path between two numerically separated waypoints into equidistant segments and stores the intermediate points in intervening waypoints.

GRI: Group Repetition Interval. Timing code used to identify the transmitters in a LORAN-C chain.

LOCAL-GMT: Sets the difference between local time and Greenwich Mean Time so that time computations can be displayed in local time.

LORAN-C: Long-Range Aid to Navigation.

MASKS: Sets the elevation, signal-to-noise, and PDOP masks for the GPS receiver.

NMEA I/O CODES: Selects the I/O codes for the three NMEA channels. I/O codes determine what information is sent to each channel.

PDOP: Position Dilution of Precision. A numerical value indicating the degree of precision of GPS information. Low PDOP values indicate higher precision. PDOP is affected by the position of the satellites in relation to each other. Closely spaced satellites provide less accurate position fixes than widely spaced satellites.

RATE: Determines how often selected data packets will be sent from the I/O ports.

S/H: Used for manual entry of speed and heading of the vehicle for dead-reckoning navigation.

SAIL MODE: Determines whether range and bearing computations are done using great circle or rhumb line.

SNR: Signal-to-noise ratio of received navigation signals.

TRIMBLE 10X HARDWARE INTERFACES

I/O CONNECTOR J1 (37 PIN SOCKET)
. . . .

NMEA I/O PORT #1 TO SEATRAC INTEGRATED NAV COMPUTER

J1-24 (XMIT-)--------------> DB25-2
J1-20 (GND)-------------> DB25-7
J1- 5 (RCV +) CONNECT J1-5 TO JI-20

. . . .
NMEA I/O PORT #2 TO AINS COMPUTER

J1-30 (XMIT-)-------------> DB25-2
J1-26 (GND)-------------> DB25-7
J1-11 (RCV +) CONNECT J1-11 TO J1-26

. . . .
NMEA I/O PORT #3 TO DIFFERENTIAL GPS PK-88 TNC RTCM-104

J1-35 (RCV-)---------------> DB25-3
J1-17 (RCV+)---------------> DB25-7
J1-32 (GND)

. . . .
CONTROL DISPLAY UNIT (CDU) J2

DB25 (PINS) HARD WIRE TO PS
. . . .
J2- 1 (24 VDC)------------> 24 VOLT POWER SUPPLY
J2- 2 (24V RTN)------------> 24 VOLT POWER SUPPLY GND
   |
   | 8 PIN CIRCULAR (SOCKETS)
   | . . . .
J2- 7 (CDU#1 RCV+)---------> CDU1-6 (XMT+)
J2- 8 (CDU#1 XMT+)---------> CDU1-4 (RCV+)
J2- 9 (CDU#1 PWR+)---------> CDU1-5 (V+)
J2-20 (CDU#1 RCV-)---------> CDU1-7 (XMT-)
J2-21 (CDU#1 XMT-)---------> CDU1-8 (RCV-)
J2-22 (CDU#1 GND)---------> CDU1-1,2 (GND,SHLD)

. . . .
BENDIX KING VHF RADIO (LMH SERIES) TO PK88 TNC INTERFACE

VHF RADIO TK88 TERMINAL NODE CONTROLLER
9 PIN SQUARE MOLEX 8 PIN CIRCULAR (SOCKETS)
. . . .
P-1 (GND)-------------------> S-1 (GND)
P-6 (REC AUDIO)------------> S-8 (REC AUDIO)
P-7 (PTT)------------------> S-3 (PTT)*
P-8 (XMIT AUDIO)-----------> S-2 (XMIT AUDIO)*

* CONNECTIONS NOT REQUIRED FOR RECEIVE ONLY SYSTEM

APPENDIX D

GLOSSARY

AINS	AUSS Integrated Navigation System
AUSS	Advanced Unmanned Search System
C/A	Course Acquisition
CGA	Color Graphics Adapter
COG	Course Over Ground
CW	Continuous Wave
DGPS	Differential Global Positioning System
DOTs	Deep-Ocean Transponders
EGA	Extended Graphics Adapter
GPS	Global Positioning System
GRI	Group Repetition Interval
INS	Integrated Navigation System
LBL	Long Baseline
LOPs	Lines of Position
LORAN-C	Long-Range Aid to Navigation
NRaD	RDT&E Division of the Naval Command, Control and Ocean Surveillance Center
PPS	Precise Position System
ROV	Remotely Operated Vehicle
SBL	Short Baseline
SOG	Speed Over Ground
SPS	Standard Positioning System
SVP	Sound Velocity Profile
TTG	Time-To-Go
USBL	Ultrashort Baseline
VGA	Video Graphics Adapter
VRU	Vertical Reference Unit
XBT	Expendable Bathythermograph

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This report describes the surface navigation and underwater tracking system capabilities used in support of the Advanced Unmanned Search System (AUSS) development program. Various surface navigation and underwater tracking modes and the hardware involved are discussed. Navigation and tracking performance objectives are stated, and where available, at-sea test data results are presented to support claims. The hardware and software necessary for the deployment and calibration of a typical underwater tracking range, used for monitoring AUSS position, are discussed.

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